Materials & Methods

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ECONOMIC ASPECTS OF ALUMINUM AND MAGNESIUM ALLOYS
L. W. Eastwood 63

MACHINING INDUSTRIAL TIMING MECHANISMS
C. R. Horton 69

MODERN MAGNETIC MATERIALS
N. E. Finke 72

INGENIOUS STEEL QUENCHING PRACTICES
Kenneth Rose 77

METALLIZED GLASS FOR JOINING OF GLASS TO METAL
Harold G. Vogt 81

MANUFACTURING ECONOMIES RESULT FROM BARREL FINISHING
Herbert Chase 84

ENGINEERING PROPERTIES OF IRON POWDER PARTS
Alexander Squire 89

CONTINUOUS SOLDERING OF SMALL MOTOR ROTORS
W. L. Tesch & Paul A. Greenmeyer 94

MANUFACTURE OF BALLS FOR BEARINGS AND PENS
James Porterfield 97

HARD-FACING MATERIALS

"MATERIALS & METHODS MANUAL" NO. 27
H. R. Clauser 103

INDEX OF FEATURE MATERIAL, VOL. 25, MATERIALS & METHODS 231

DEPARTMENTS

Production Frontiers 3
The Materials Outlook 8
Editorials 59
Contents Noted 120
Engineering File Facts 123
Materials & Methods Digest 127
Book Reviews 133
Shop Notes 136
Manufacturers' Literature 138
New Materials and Equipment 143
Advertisers and Their Agencies 229
The Last Word 234

NEXT ISSUE: Titanium in Cast Bronzes . . . New Flux for Soldering on Zinc . . . Submerged Melt Welding of Corrosion Resistant Materials . . . Piercing Holes on Presses . . . Porcelain Enamel . . . Strippable Plastic Coatings . . . Carburizing Steel Parts With the Salt Bath

LOW ALLOY, HIGH STRENGTH STEELS
Materials & Methods Manual No. 28

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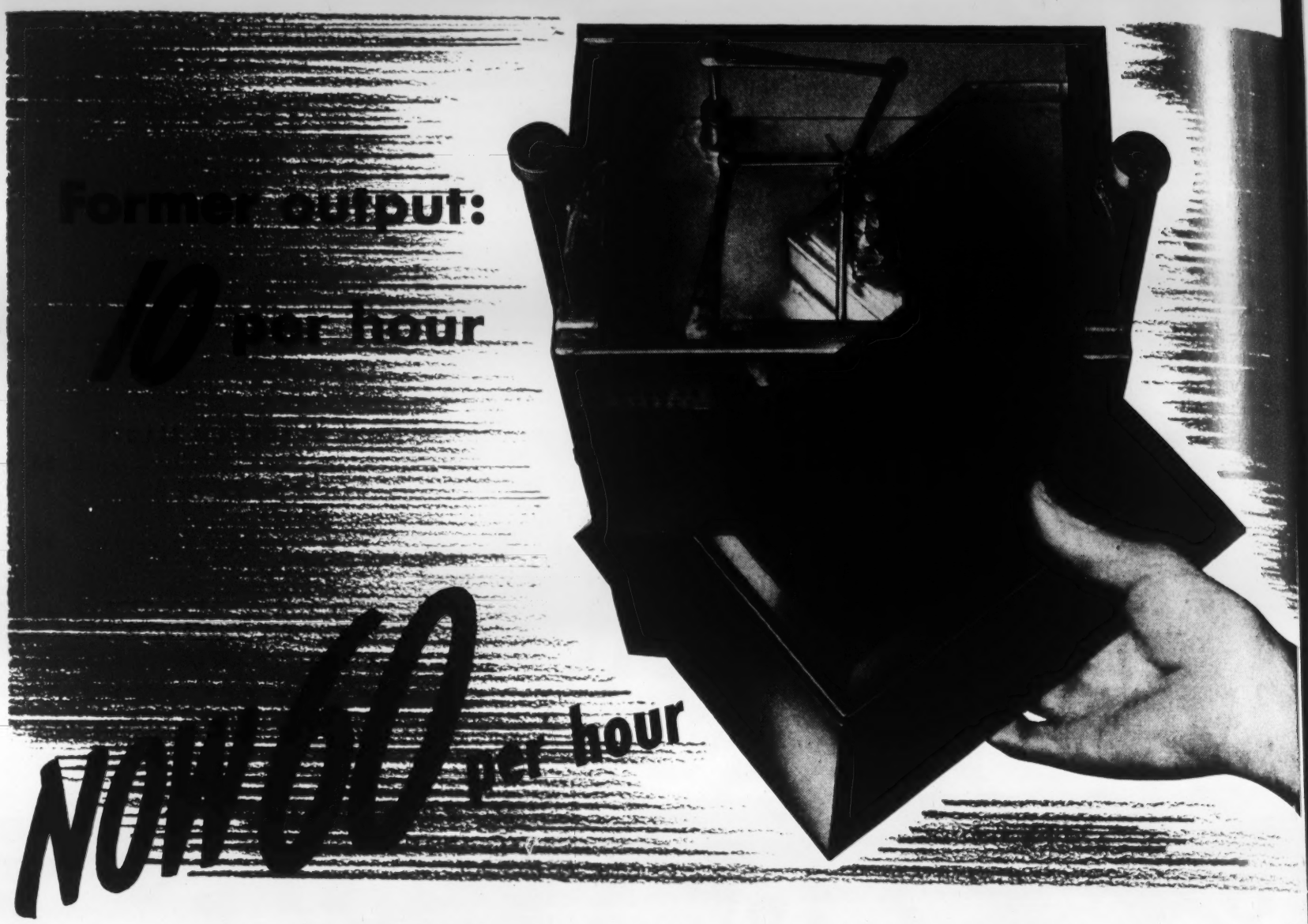

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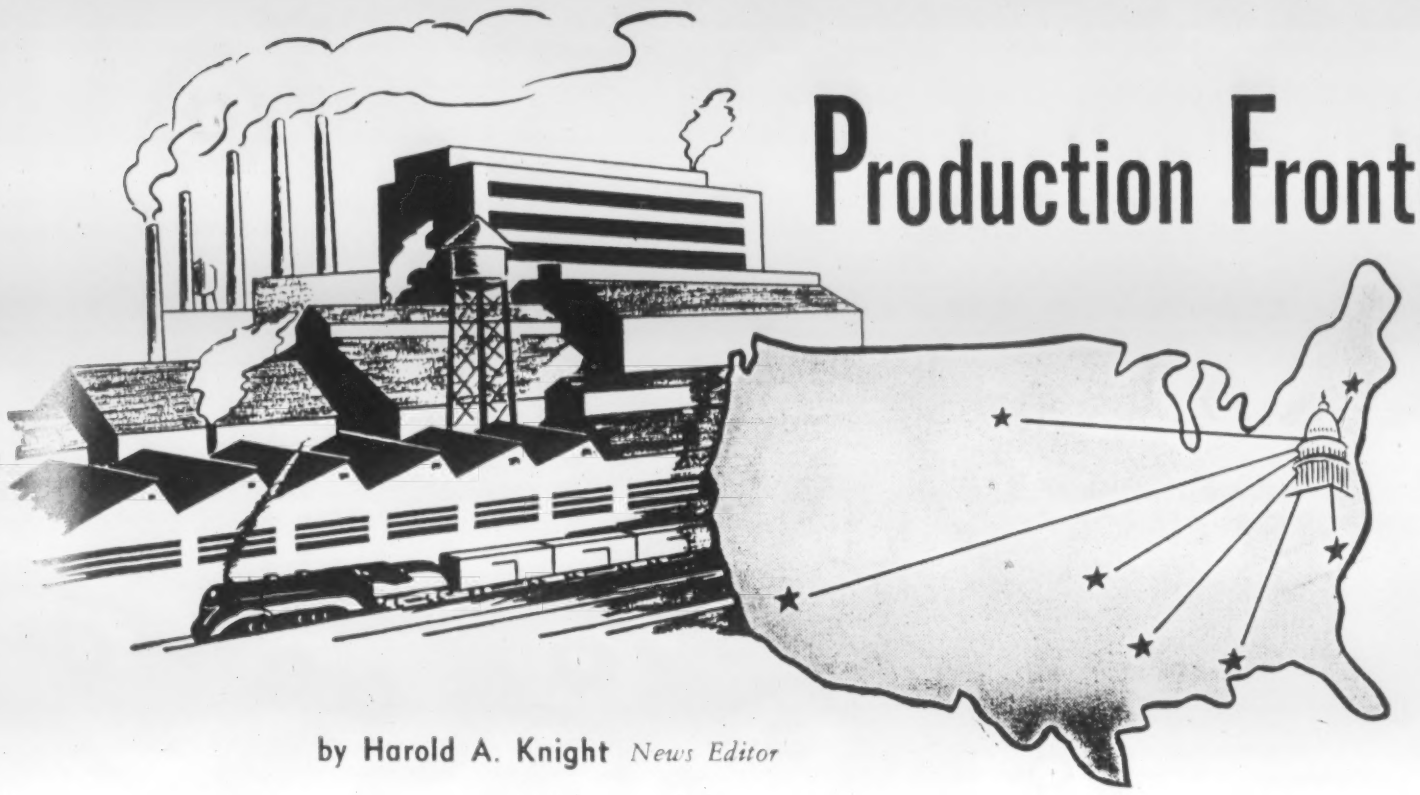

Production Frontiers

by Harold A. Knight *News Editor*

Talk-Talk on "Situation" Crescendos

Roosters crow and birds sing with unusual gusto before a change of weather. The rooster, when you study him closely, is a magnificent bird and one with many moods. He feels responsible for keeping up the morale of his flock. Often he crows just from a sense of vanity and to impress the females; at other times he is warning the females of some impending danger; at other times he is scolding them for some female foible, such as the equivalent in the poultry world of painting their toenails.

Which brings us up to the point that in the human world there has been much crowing or vocalizing the past month on the situation—economic, world, labor—some of it, like the rooster, in a boastful vein, some of a warning nature and some of a carping character.

This sudden burst of vocalizing on the part of economists, industrialists, professors and leaders of the people may ominously portend some change in the weather. Does it indicate that the much-heralded recession is about to set in? A prognosticator of things economic might well add another line to his chart, labeled "talk-talk." In short, when a crescendo in talk materializes, look for a change in economic weather.

In replying to President Truman's urge for price reductions, Earl Bunting, president, National Assn. of Manufacturers, stated that whereas since 1939 wages have increased 85%, agricultural prices 180% and raw industrial materials prices 135%, prices of manufactured goods, as of May 1, have advanced but 75%.

Again, on the side of manufacturers, Frank Purnell, president, Youngstown Sheet & Tube Co., told stockholders: "Necessity for higher profits in the steel industry was never so pronounced as today. For many years depreciation was calculated as nearly sufficient to pay for replacements. Costs of construction and of new equipment have by now increased to a point where reserves built up by depreciation will cover only a portion of the cost of replacement—in fact, reserve is often less than one-fourth of the replacement costs."

Says It's Solely Up to Management

Here is one industrialist, at least, who fully assumes management's responsibility, and perhaps even more. He is Gen. Brehon Somervell, president, Koppers Co., Inc., who said that "management must prove its ability to provide a stable economy that is satisfactory to the people as a whole —or see the American system of free enterprise replaced."

And speaking of free enterprise, the Twentieth Century Fund proclaims: "Far from being mature or dead, the American economic system is a dynamic, growing thing. It holds possibilities for capital expenditures; for starting new businesses, for producing such capital goods as new factories, stores, new school buildings, hospitals, highways, railroads, etc. probably beyond our capacity, so that a vast area for still greater expansion lies in the future."

Wilfred Sykes, president, Inland Steel Co., recently contributed some novel ideas, expressed with oomph. He said: "We will have to scrutinize rather carefully some of the extravagant ideas of our bright boys in business. A boom always brings along the bright boys whose balloons are punctured when adversity strikes—such boys in our business, but on a vaster scale in government." And again he says: "Don't think our labor leaders have reformed. Most are scared as to the effect that legislation may have on their vested interests. In the case of the leader of the coal mines, we are dealing more with a psychopathic case than with a normal American and if the government is realistic they will treat him as such."

Talking on "Roots and Fruits of Boom," Bradford B. Smith, economist, U. S. Steel Corp., concluded: "The roots of inflationary boom are public ignorance about or indifference to the

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meaning of honest money (as contrasted to mere "printing press" money) and the means of maintaining it; the fruits of boom are injustice, wasted resources and economic maladjustment while it lasts, and deflationary depression, unemployment and social unrest when it is over."

Optimistic is William L. Batt, president, SKF Industries, Inc., who said: "I do not believe there is any likelihood of a severe depression, such as in the 1930's, at any time in the predictable future but we are now facing a critical period of business readjustment."

On the psychology of labor the Committee for Economic Development presented an interesting case history. In a metalworking plant a dispute over the bases for progression within rate changes threatened to produce a stoppage of several thousand employees. The parties had argued so long that any utterance of either party was rejected immediately by the other. The mediator who was called in talked with each party and had a hunch. The hunch was this: Each party was objecting, not to the substance of the *other's* proposal, but to the fact that it was the other's proposal. Acting on this hunch, the mediator produced a proposal in *his* words that was immediately acceptable to both sides. Each side insisted that the proposal represented what *it* had been suggesting all along.

Germans: Humans and Technicians

Have the German chemists, physicists and engineers been reluctant to cooperate with Americans in revealing German war secrets? The answer is "only rarely." Never in history has Germany been so completely crushed in defeat. There are no illusions in that country and they are not secretly preparing for another war as they were at the end of War I. Except for a few fanatics skulking underground, the German rank and file entertains no ambitions for Germany to rise again to the position of an aggressive world power.

So speaks Clayton F. Ruebensaal, technical director, Plastics & Chemicals Div., Glenn L. Martin Co., through the *Martin Star,* house organ of the Martin company. It is one of the most interesting descriptions of Germany today we have seen.

The German scientists have nothing to lose by cooperation with us and everything to gain. Many still hope to be brought to the United States for research work and consultation. Many scientists have hope for nothing further than enough cigarettes, butter and food.

A striking observation of Mr Ruebensaal was work on the use of plastics in the human body at Munich. They inject a special form of polyvinyl alcohol into parts of the body, this later becoming solid to reinforce collapsed lungs, etc., finally becoming an integral part of the body itself. He saw the lung of a rabbit where the plastic had fibered, with blood vessels growing through it. A possibility is the affixing of a base to a human body of these plastics to which artificial legs and arms can be attached.

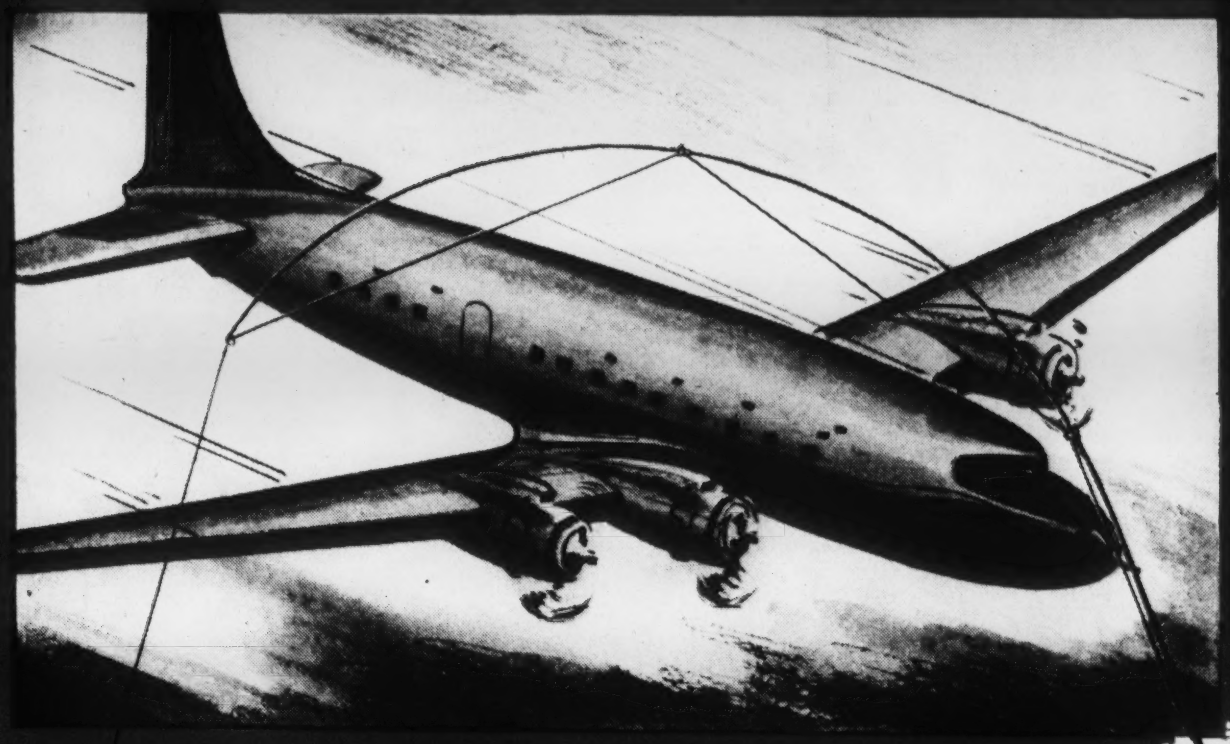
Another plastic is a new series of polymers known as polyvinyl pyrrolidones which are water soluble and find application as a blood substitute. At least a half of the total blood in a person could be replaced by a dilute solution of this albumen-like plastic. The German army used it for blood transfusions. Also methacrylates for skull insertions and artificial eyes and polyvinyl chloride for artificial hands were observed, though the United States has already done better here.

Also at Munich was an export exhibition where were exquisite glass, pottery, fine silver jewelry, sporting goods, precision instruments, basketware and cloth art work.

Mr. Ruebensaal inspected a German barter market where people bring in personal belongings and turn them in for points for buying cigarettes, food, or candy. Thus, American cigarettes are valued at 55 points per carton. A Contax or Leica camera is worth about 3000 points.

His comments on the residents at Bad Homburg are: "Even when walk-

"Sure I've had boring experience—my friends say I've bored them for years!"



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ing in the parks they still appear very strained. Their attitude and conversations with us are very subservient and make us feel rather self conscious. It is different in the larger cities where they are better accustomed to Americans."

Speaking of an I. G. Farben plant, he said: "The director has several assistants who keep running in and out all day chattering most of the time and chewing on something the rest of the time. They eat so much it gets me nervous—continually gnawing on an apple, pretzel, hard roll or a turnip. No, they were not afraid they'll never eat again. I was told the Germans have always been like that."

Mr. Ruebensaal implies that German technicians generally were overrated. German know-how before and during the war was not in many cases as advanced as ours. However, the addition of their methods to ours adds greatly to the sum total of American resourcefulness in chemistry. Even where they uncovered unworkable theories they added to know-how. We can start off on different paths and do not have to duplicate their failures.

Banker Asks About Aluminum

The economist of a New York bank called us up and propounded a question: "When steel becomes plentiful again, to what extent will it crowd out aluminum in the building and housing field?" Willing to stick our neck out at the drop of a hat (more properly, our hat drops off when we stick our neck out) we answered him about as follows:

Let's assume that in new construction 60% of the items in a home, farm or business building that were formerly of steel are now of aluminum. When steel becomes plentiful the aluminum percentage will drop to 40%. However, because of increasingly large volume of construction over the next several years, and new applications, the total tonnage of aluminum so consumed will increase, even if percentage as against steel declines.

Present chief uses of aluminum in buildings are for windows and roofs, the latter in place of scarce galvanized steel. But we shall see several more adaptations of aluminum, such as in walls, having good permanent surface, low maintenance, heat reflection and low cost. So far, its use as walls or panels has been as a copy of wood clapboards or shingles. Some day aluminum will stand on its own bottom and aluminum will resemble itself.

Aluminum windows eliminate paint, are neat, light and comparatively cheap. In a new type glass panes slide inside the weather strips, eliminating putty. When we visited Alcoa, Tenn., the heart of the aluminum producing district, we saw shower bath stalls lined with embossed aluminum sheets, practical, attractive, easy to install. They are more durable than painted steel and cheaper than porcelain enamel, with labor for installation very cheap. Around Alcoa, too, home lighting fixtures were of aluminum and were very attractive. Elsewhere than in Alcoa we have seen many aluminum door knobs, often given a color finish to resemble brass.

As to roofing for farm buildings, a thrifty farmer may weigh galvanized sheets which last perhaps 15 years and aluminum roofing which should endure as long as the building.

The banker thanked us cordially. We don't know to what degree he had been convinced.

Nickel

What might be termed "little known facts about a well-known metal" we glean from the annual report to stockholders of Robert C. Stanley, chairman and president, International Nickel Co. of Canada, Ltd. Pure nickel is well suited for coinage because of its appearance, resistance to wear and difficulty of counterfeiting. The fact that it is strongly magnetic further aids this last quality.

Nickel has been used for coinage purposes since 1850, and the first pure nickel coins were issued in 1881. Over 100 governments have used nickel, either pure or as an alloy, as a part of their coinage systems. During 1946 India substituted pure nickel for part of its silver coinage; Canada resumed issuance of pure nickel 5-cent pieces; British silver coinage was replaced by cupro-nickel; the United States resumed minting its cupro-nickel 5-cent piece; Luxembourg resumed issuance of 1-franc cupro-nickel pieces, France using the same alloy for 10-franc pieces. Many other countries contemplate similar action.

The geographical distribution of nickel sales by International Nickel have changed greatly since the war. Russia, formerly a very important market, did not buy any Canadian nickel in 1946 and is developing the Petsamo nickel mine from territory conquered in war. Both Japan and Germany have been eliminated completely as industrial consumers. Sales in the United States and many smaller countries have increased so that total sales are equal to best pre-war years.

In the United States the steel industry is still the largest consumer of nickel, over half going into the manufacture of stainless steel. And stainless production now runs 550,000 tons yearly, or five times that of ten years ago. Over 40,000,000 lb. of primary nickel is needed for this modern stainless production yearly.

Leaving Mr. Stanley's sober and interesting appraisal of the nickel situation, we close on a somewhat silly note. We just mentioned we have lost our nickel markets in Russia, Germany and Japan. We note, too, we have lost our "nickel, nickel, nickel" in the radio jingle—the "Pepsi-Cola hits the spot." No longer does that jingle taper off in the nickel refrain. Alas, inflation! Your favorite beverage no longer sells for a nickel.

Cops Heat Treat With Pistols

Now that the play, "Annie Get Your Gun," has a current run on Broadway, they're reviving tales of the fabulous Annie Oakley, one of which concerns a cat that climbed a tree and, like so many pussies in a similar situation, was afraid to come down. There sat somebody's precious on a 2-in. O.D. limb, refusing to be tempted down by milk and fish. The fire department had already been assembled, with net spread. Enter Annie Oakley. Six bangs from her 6-shooter and she cuts through the limb and down comes limb and pussy.

Now comes along her brother, let us say, Johnnie Oakley, company policeman at the Saginaw Malleable Iron Div. The scene is a heat-treating kiln, 1,300 ft. long with temperature of 1,700 F. The work is carried into the kiln on cars on tracks. A refractory brick falls out of place and blocks the car 600 ft. inside.

Plan No. 1 is to let the kiln cool for two days. Then a man enters with asbestos suit and removes the brick. Then several days for reheating.

But in Plan No. 2, Johnnie Oakley pulls out his pistol. The first few shots miss but the sixth .38 slug dissolves the brick in a cloud of dust.

The MATERIALS OUTLOOK...

General Situation

No single influence on business so far in 1947 has been more pronounced than President Truman's frequent insistence that manufacturers reduce prices. This soon bore mild results as to actual reductions, but perhaps the greatest effect has so far been psychological. It has tended to make the public postpone buying. So what is now psychological may soon be translated into definitely lower prices so that an average reduction in all goods of 20% by July 1 seems logical. In many lines there is a surplus of goods such as brass goods among plain materials and radios among finished goods, resulting in sharp unemployment in the radio industry. Metal producers frankly admit that prices will come down soon, the question being how much. This great mass producing nation rapidly falls into its stride of big time output, scarcities becoming rare exceptions. Most economists agree that comparatively low prices and mammoth production are the magic formula.

Aluminum Ever More Plentiful

Let's call aluminum the "No. 1 bountiful metal." It is freest in supply and promises to so continue. All new production facilities leased or purchased by the second largest producer are now at peak production. The president of the largest producer says: "The time is fast approaching when we'll have to beat the bushes for orders." To cap the climax, aluminum is the only metal during this post-war era that has not risen in price. Even heavy metal lead is a cent higher than light weight aluminum where you get so much for your money in volume. No wonder lead has almost completely lost out in the foil and collapsible tube fields to aluminum!

Ease Up on Tungsten

Not long ago the price of tungsten ore (wolframite) was advanced in price from $22 per unit to $30. It is significant when any metal price rises in this pressurized era for lower prices. The war time cycle is starting all over and smart cutting tool manufacturers will probably again use molybdenum where they can. A world wide surge of demand for tungsten for high temperature hardening elements is now rife. Swedish tungsten-bearing products are going to Russia for stock-piling. There is a big demand for the comparatively new tungsten carbide for cutting and machining. China is far from normal as an exporter. Tungsten carbide cores for bullets and shells will be a must in the next war.

Lead Situation Better

The lead supply never became quite so bad as many feared. The situation improves and will continue to do so and even producers talk of the day, not too far distant, when prices will decline from 15¢. This record high price has brought out raw supplies that weren't known to exist in form of scrap, matte, flue dust, etc. Some producers are working over "tailings," accumulated before the flotation process, recovering 20 lb. of lead per ton, or $3 worth (call it "hay," but worthwhile). The strike at Western Electric slowed down consumption. The high price has brought much foreign lead to the U. S. So, count on receiving almost normal supplies soon, although for long range planning it would be wise to investigate other suitable materials.

More Commercial Beryllium

This up-and-coming metal promises to be more plentiful because of studies made to beneficiate low grade beryl-bearing ores in three New England states. The ores are amenable to flotation after desliming and vigorous surface conditioning with caustic soda, trisodium phosphate or hydrofluoric acid. The New England ore location is fortunate because nearly half the world's production is consumed by the New England brass industry.

Have You Considered Platinum?

You may have forgotten about platinum, which was difficult to procure for peace purposes during t war and which priced itself out of t market when price controls were moved on April 29, rising to $93 p oz. But by now the platinum mark has returned to normal, and as th is written the price is around $6 Use of substitutes for the electric industry and jewelry, such as palla ium, has taken much of the burde off platinum.

Using More Abundant Metals

Far-sighted metallurgists are wor ing feverishly to put to work th more abundant metals and minera that so far have enjoyed moderate small use, thereby relieving scarciti of the more common metals. Zircon ium and titanium, for instance, a extremely abundant, their use is ex panding rapidly now, and it is hope they will become major metals. Sil con, too, is extremely plentiful i nature and perhaps can do more t the world's work. Maybe a way ca be found to prevent calcium fro slowly burning itself up.

Hey Day for Polyethylene

A materials engineer with a larg manufacturer of electrical goods pre dicts a tremendous jump in his own consumption of polyethylene in 194 because of its proven superb qualities Thus, mixed with carbon black an used with thin sheets of aluminum and bonded with an adhesive, it may supplant lead as a cable sheathing The excellent insulating properties o polyethylene are proving of grea value in the electrical field. Though one of the newest members of the thermoplastic materials, it has become so important that the Carbide & Car bon Chemicals Corp. plans to double its wartime production of polyethyl ene resins at its South Charleston, W Va., plant. This material during the war was a major advance in the field of radar. Its use has spread to appli cations never dreamed of at first. It remains tough and flexible over a very wide temperature range. It has low-loss electrical properties and is so light it will float on water.

AN
EDITORIAL

A Mountain of Molehills

A lot of people (including us) are all worked up over the current shortage of certain important industrial materials—especially sheet steel, tin, lead and certain plastics. The persons most exercised, of course, are those whose production is slowed or stopped because of the shortages, and they include some mighty important manufacturers. The suppliers involved are unhappy about it too, because on top of whatever specific headache is causing their particular shortage, they have to accept considerable abuse from their customers. They are naturally rueful, too, about turning away perfectly good business simply because of their inability to deliver.

Then there is shouting in Washington and by industrial groups and by consumer organizations and others, and from all the noise and excitement it certainly looks as though we have a mountain of trouble on our hands and, indeed, that most of our national economic problems could be directly attributed to material shortages. A little thought on the matter has convinced us, however, that this one molehill couldn't make all that mountain and that actually several molehills must be involved.

In the first place, the shortages mentioned are very real and very painful, but the most important among them (sheet steel and the plastics based on formaldehyde) are "temporary" in the sense that they should be eliminated within six months to a year. Beyond that most materials used by industry are now in reasonably good supply and their salesmen have returned from their hideouts and are ringing doorbells again with oldtime vigor and promiscuity.

The real problems facing industry today go 'way beyond materials. One of the greatest is the fear of an imminent depression. Actually, we are having a recession right now, which (in the opinion of many people better informed than we) will not be much more serious than it is at present and will be over in a few months. Some of the reliable forerunners of trends in our field (*e.g.* orders and sales of heat treating furnaces) indicate that a very healthy and active period is almost directly ahead of us.

An obvious cause of the present slow-down in business is increasing buyer resistance to existing prices, especially of consumer products, which of course backs up to the industries behind their manufacture. Coupled with this is growing insistence by consumers on higher product quality than has been customary in the past two years.

Then there is underway an adjustment of production facilities, many plants being expensively over-equipped in some directions and under-outfitted in others. And finally we have to face the fact that our productivity sank lower during the war than we care to admit, and it will be some time, with the aid of smart re-tooling and better planning and control, before it again reaches a respectable level.

Material shortages are a problem, but there are other problems, too. If we're going to break up the molehills that make up the mountain, let's be sure to identify and locate them all, rather than just one.

FRED P. PETERS

EDITORIAL COMMENT

A New Challenge to Materials

"It's an ill wind that blows no good." All wars are ill winds, and the most recent one was certainly no exception, but it is also true that it has blown much good. Another instance of a wartime development that will have tremendous long-range benefits for American industry was pointed out at the Industrial Packaging and Materials Handling Exposition, held recently at Chicago.

It is not generally recognized that, while America's mass production industries met production goals set by global war, the distribution system bogged down completely, Norman L. Cahners, president of Modern Materials Handling Laboratory, told the exposition forum. It was not the railroads, nor the overseas shipping, but the handling of goods by peacetime procedures that caused warehouses to fill to overflowing and ports to become bottlenecks. In breaking these bottlenecks there came a discovery. Mass production techniques, meaning the breaking down of a process into its unit operations, had developed efficient methods for moving work through the plant as a matter of course—"We'll make it on a belt line" had become a cliche—but handling of goods in distribution had never been generally recognized as a specific function.

The term "materials handling" was adopted, and a Materials Handling Department was set up in Washington to systematize, coordinate, and mechanize work that had formerly been known as stowing, stacking, piling, car loading and unloading, stevedoring, etc. Such progress was made, said Mr. Cahners, that, "At the war's end, sardines were being palletized at a canner's plant in Lubec, Maine, and were moving on that same pallet through all transportation and warehousing processes in this country, and were moving overseas and on beachheads under fire, finally to arrive at dispersal areas still on the same pallet."

Industry is beginning to recognize the savings possible by systematizing, coordinating, and mechanizing the handling of its product after it leaves the plant. The Department of Commerce has set standard sizes of pallets for various industries to assure maximum utilization of space in freight cars, minimum handling of the goods in transit, and possibility of doing most of the handling with mechanical equipment, such as fork trucks and standard conveyors. There is a reawakened interest in such things as bulk packing, unit loading, and mechanized handling. The thinking extends back into the plant, as well as forward, to goods in distribution. The perfect handling system for steel would presumably begin at the iron mines, move the material to and through plant after plant until it wound up in the hands of the ultimate consumer, with all handling methods and equipment to, through, and from each plant coordinated and mechanized. A distant goal, truly, but one that promises substantial rewards when ultimately attained.

There is a market here, and a new challenge to the engineer. New and better equipment will be designed, offered for sale, and bought according to its merits. Standard designs will be reexamined to see whether they can be improved by use of new materials. New tote boxes of corrugated steel sheet, and of steel rod, have appeared. Improved pallets of steel and of aluminum have been announced. An aluminum acid drum is certified. Magnesium dock boards go into service. A large midwestern concern considers magnesium shipping containers. Paperboard mills double their capacity over the prewar figure in preparation for a wide expansion in the use of packaging. A hard paper strap appears to compete with steel. Transparent and window containers will make use of increased amounts of cellophane and plastics. Fiber-faced plywood prepares to carry air cargo. The challenge is being accepted.

—K. R.

More Government Regulation?

Over-all planning and policy making, and self-regulation in industry are not inherent characteristics of a free enterprise system such as ours. And one of the big questions today is: In the future will these problems be handled by government through legislation, commissions and the like, or will they be handled largely by industry through their own voluntary and cooperative efforts?

In recent years the trend has been towards increased governmental activity in these matters. One reason for this has been the reluctance of industry to take constructive action towards solving many of the industrial, social and economic problems that are constantly arising in our ever-growing, highly complex society. Justice Frankfurter once said, "It is too often overlooked that government as a rule undertakes no services or regulations except after private agencies have proved themselves incapable or unwilling." Thus, the pure food and drug laws, the Federal Power Commission, many of our present banking laws, and state safety codes were established after private agencies failed to get together and resolve such matters on their own initiative.

That industry can get together collectively has been proved by the success achieved in standardization on technical matters such as dimensional standardization for interchangeability of parts, specifications, and tests and testing methods for materials. Organizations such as the American Society for Testing Materials, the American Standards Association and many other trade associations and technical societies are doing an outstanding job. However, the large general organizations like the National Association of Manufacturers have given only minor attention to over-all and integrated policy making and self-regulation. Although technical matters may be narrower in scope, the bickerings, jealousies, and politics that arise in arriving at solutions satisfactory to all concerned are quite the same as those encountered in most human groups.

It is encouraging to see that a number of progressive business men like Beardsley Ruml, Eric Johnston, Paul Hoffman and Charles Luckman acknowledge the responsibility of industry for economic planning and self-regulation. Through their Committee for Economic Development some business leaders have begun to lay the groundwork for taking constructive action.

So, it is to a large extent up to industry. If it is to avoid a lot of government regulation and interference in the future, it must, through constructive action, work out solutions to the problems, which are also public problems, before government legislation becomes necessary.

—H. R. C.

Materials & Methods
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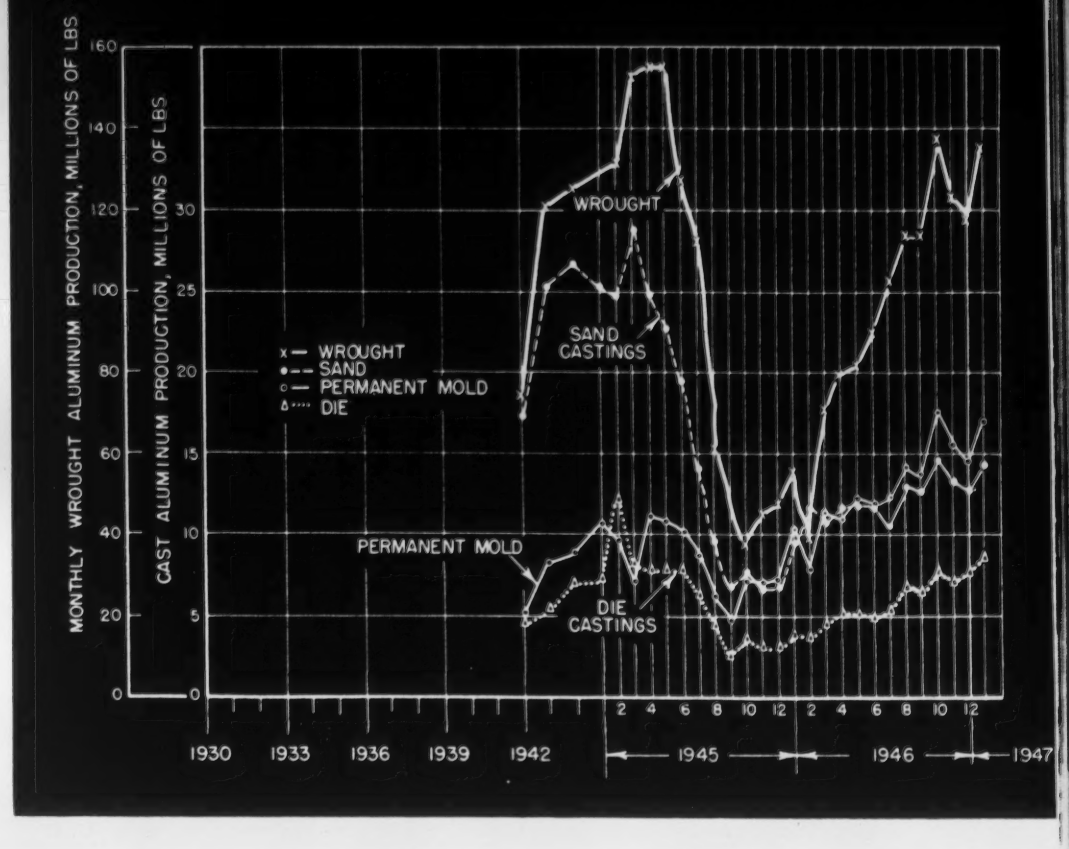


Production of sand-, permanent mold-, and die-cast and wrought aluminum products in the United States.

Economic Aspects in the Use of Aluminum and Magnesium Alloys

by **L. W. EASTWOOD,** *Ass't. Supervisor, Process Metallurgy Div., Battelle Memorial Institute*

CHOICE OF THE MOST SUITABLE METAL for use in any given part must be based on considerations of the factors of price, physical properties and formability. The use of aluminum and magnesium alloys has increased tremendously in the recent years because of their excellent physical properties. However, their use is limited to applications in which requirements for specific properties or possible forming economies will compensate for their high cost.

The many favorable characteristics of the light metals which make their use desirable must be balanced against a somewhat higher cost of fabrication.

Aluminum and magnesium alloys are ideal for use when maximum stiffness must be combined with minimum weight. The corrosion resistance of aluminum makes it more suitable than steel in many applications. Machining economies possible with permanent mold or die castings of aluminum or magnesium have led to their use in many parts that were formerly made of cast iron.

Increases in the field of application of aluminum and magnesium have led to increased production of these metals. Their cost of production has decreased progressively as quantities produced have increased. However, high costs of fabrication have usually kept the prices of aluminum or magnesium parts much higher than the prices of similar parts made of ferrous materials.

Comparisons of the prices of various ferrous and light-alloy products are made in Tables 1 to 5, in-

clusive. When making these comparisons, the general procedure was to obtain an average or composite price of the metal in cast or wrought form, expressed in dollars per pound. From this value, the price of the metal was subtracted which would, in effect, express the relative price of fabricating or casting the metal. Dividing this figure by the number of cubic inches of metal in a pound produces the relative price of fabricating 1 cu. in. of the metal, thereby placing metals having different densities on the same basis.

Cost of Castings

Employing this general procedure, it is observed from the data in Table 1 that the price of manufacturing or making a rough magnesium casting, exclusive of the metal cost, was 6.8, 8.4, and 8.2 times the price of making a rough gray iron casting in the years 1939, 1940, and 1941, respectively. There are a number of reasons why the price charged to make a magnesium casting is 6 to 8 times the price charged to make a gray iron casting. Magnesium requires an expensive sand, and the melting and metal-handling procedures are cumbersome although substantial progress has been made in this respect recently. Another reason for the high cost of magnesium castings is that most of them have been of aircraft quality. In many cases, unnecessarily great emphasis has been placed upon appearance, resulting in very high cleaning costs. Apparently, it is difficult for the purchaser of magnesium castings to get away from

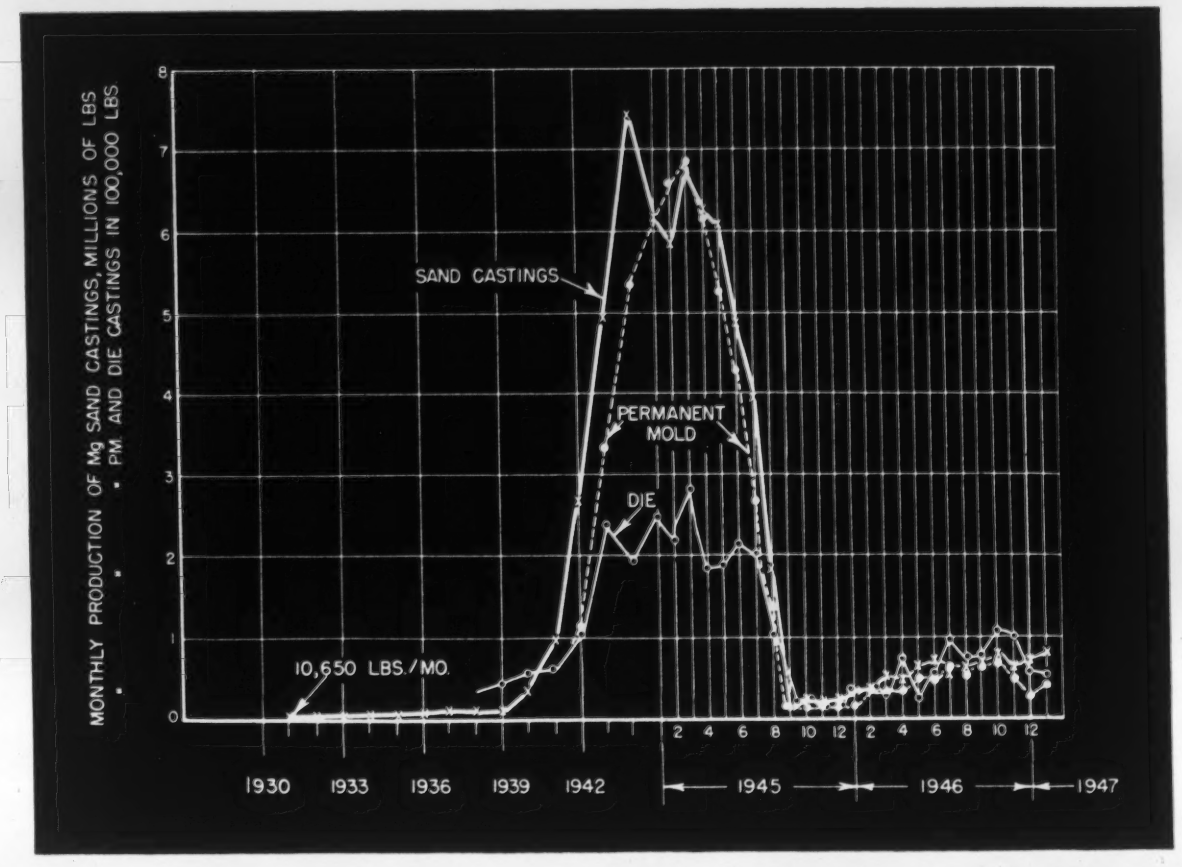
Table 1—Comparison of Casting Costs of Magnesium and Cast Iron

	1939	1940	1941
Price of Mg sand and permanent mold castings/lb.	$1.53	$1.85	$2.06
Price of Mg metal in ingot form/lb.	0.27	0.27	0.225
Price of manufacturing of rough Mg castings/lb.	1.26	1.58	1.735
Price of manufacturing of rough Mg castings/cu. in.	0.0835	0.1045	0.1147
Average price of rough gray iron/lb.	0.06(Est.)	0.0609	0.0676
Price of pig iron/lb.	0.0106	0.0113	0.0118
Price of manufacturing rough gray iron castings/lb.	0.0494	0.0496	0.0558
Price of manufacturing rough gray iron castings/cu. in.	0.0123	0.0124	0.0139
Ratio: $\frac{\text{Price of manufacturing 1 cu. in. rough Mg castings}}{\text{Price of manufacturing 1 cu. in. rough gray iron castings}}$	6.8	8.4	8.2
Price of rough Mg castings if cost of manufacturing were same as for gray iron/lb.	$0.45	$0.45	$0.44
Price of rough Mg castings to be equivalent to gray iron/lb.	0.23	0.235	0.26

Table 2—Comparison of Costs of Magnesium and Cast Iron*

	Part					
	A	B	C	D	E	Average
$\frac{\text{Cost rough Mg casting}}{\text{Cost rough C.I. casting}}$	3.5	3.0	3.6	2.5	2.9	2.9
$\frac{\text{Cost rough Mg casting per lb.}}{\text{Cost rough C.I. casting per lb.}}$	13.3	11.4	13.7	9.5	11.0	11.0
$\frac{\text{Cost machining Mg casting}}{\text{Cost machining gray iron casting}}$	0.61	0.61	0.71	0.75	0.78	0.69

*Analysis by S. Crowther, Western Metals, May, 1944.



Production of magnesium sand-, permanent mold-, and die castings in the United States.

aircraft quality for other purposes and, by the same token, it is also difficult for the foundry to give up aircraft-quality prices.

Table 2 contains data on the comparison of cost of magnesium and gray iron casting. This comparison was made on the basis of five different castings. According to this analysis, the cost of the rough magnesium castings is only 2.9 times that of the corresponding gray iron castings. This ratio is undoubtedly low, as indicated by the data in Table 1, but the average cost of machining the magnesium castings was only 69% of that required for the gray iron castings. In these particular instances the cost of machined magnesium castings was less per piece than the machined gray iron castings.

A comparison is made of the price of casting aluminum and gray iron, which is given in Table 3. It will be noted that the price of making a rough aluminum casting is twice that of making a rough gray iron casting. This, again, is probably because the yield in an aluminum foundry is somewhat less than that in a gray iron foundry. In most other

Table 3—Comparison of Casting Costs of Aluminum and Gray Iron

	1937
Price of rough Al sand and permanent mold castings/lb.	$0.45
Price of rough Al ingot/lb.	0.20
Price of manufacturing rough Al castings/lb.	0.25
Price of manufacturing rough Al castings/cu. in.	0.025
Estimated price of manufacturing rough gray iron castings/cu. in.	0.0123
Ratio: $\frac{\text{Cost of manufacturing 1 cu. in. rough Al castings}}{\text{Cost of manufacturing 1 cu. in. rough gray iron castings}}$	2
Price of rough Al castings if price of manufacturing were the same as that for cast iron/lb.	$0.32
Price of rough Al casting to be equivalent to gray iron/lb.	0.15

respects, the low-cost advantages should lie with the aluminum foundry.

Cost of Wrought Products

The data contained in Table 4 show a comparison of the price of fabricating magnesium and steel. The same procedure of making the comparisons was used. It will be noted that the price of fabricating magnesium, aside from the metal cost, is 6.6 to 10 times that required to fabricate the same volume of steel. As in previous comparisons, the difference in cost of metal are removed so that the comparison can be made directly on the price of fabrication. The wrought products of magnesium are produced on a fairly limited scale and the large difference in price as compared with steel is probably largely caused by the relatively small scale of operation and, as a consequence, the lack of good engineering and mass-production methods.

Similar data showing the comparison of the fabricating costs of aluminum and steel are listed in Table 5. It will be observed that it costs 3.6 to 4.2 times as much to fabricate aluminum as steel. The economic conditions existing for wrought-aluminum products has improved considerably as a result of the reduction in price of both the metal and fabricated products and the large-scale production methods now being applied.

Mechanical Properties

A comparison of the various mechanical properties of a number of structural materials is shown in Table 6. The upper portion of this table lists typical tensile, shear, fatigue, and modulus values for four ferrous products, a typical aluminum sand-cast alloy, a typical aluminum high-strength wrought alloy, a typical magnesium-wrought alloy, and a typical heat-treated magnesium casting alloy. The lower part of the table contains data on property-weight ratios.

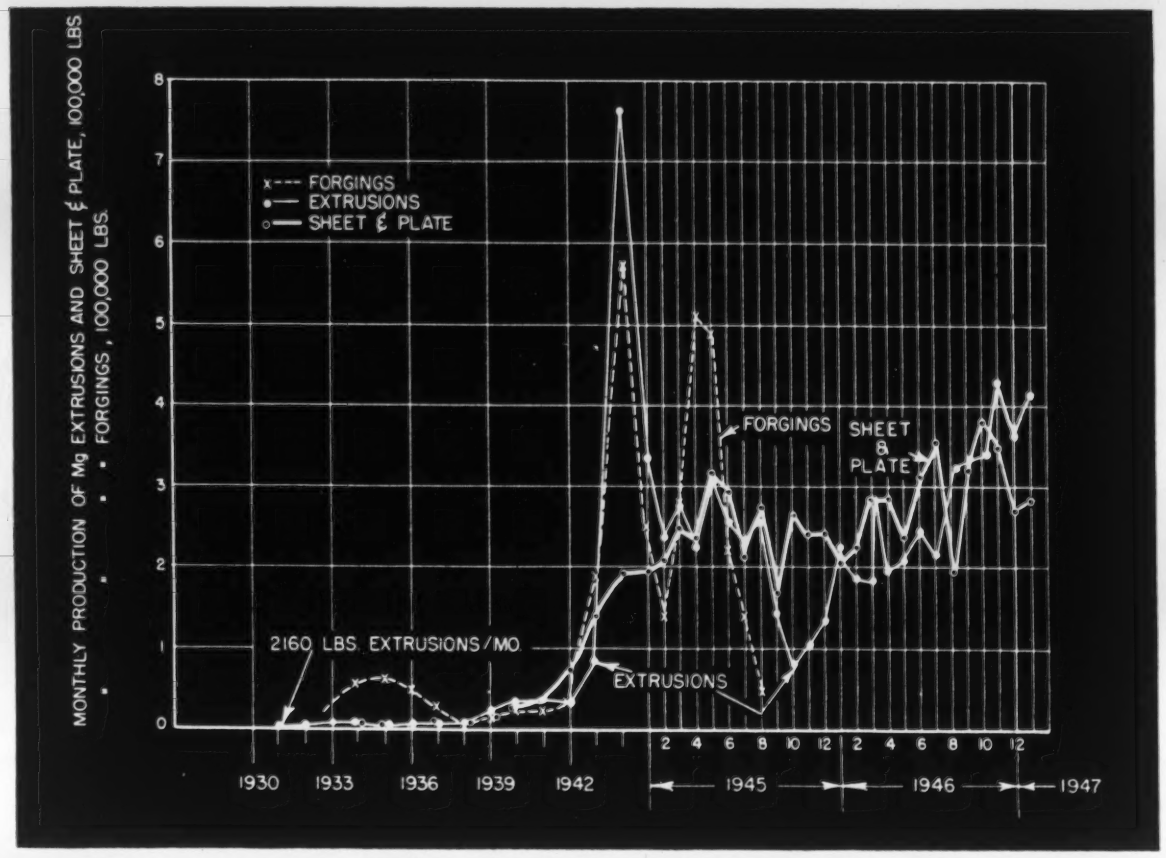
Of these ratios, the first is of most importance in castings where the same section thicknesses can frequently be used since the limiting thickness is determined not upon properties but upon the ability of the founder to cast the section. The fifth and sixth ratios are largely of interest where resistance to the buckling of sheet is important. In all of these ratios, mild steel is taken as a unity. The general superiority of both aluminum and magnesium alloys is readily apparent. It should be noted, however, that none of these advantages would be significant unless it was desirable to have a structure of minimum weight.

Fabricating Characteristics

The amenability of various wrought alloys to fabrication into the finished products is difficult to rate.

Table 4—Comparison of Fabricating Costs of Magnesium and Steel

	1939	1940	1941	Feb. 1947
Price of Mg sheet /lb.	$0.643	$0.767	$0.718	—
Price of Mg structural extrusion/lb.	0.602	0.850	0.695	—
Approx. composite price of Mg sheet and extrusion/lb.	0.62	0.80	0.71	$0.55
Price of Mg metal/lb.	0.27	0.27	0.225	0.205
Price of manufacturing Mg wrought products/lb.	0.35	0.53	0.485	0.345
Price of manufacturing Mg wrought products/cu. in.	0.0232	0.0352	0.0321	0.0235
Composite price of finished steel/lb.	0.0264	0.0265	0.0265	0.031
Price of steel billets/lb.	0.017	0.017	0.017	0.018
Price of manufacturing finished steel/lb.	0.0084	0.0095	0.0095	0.013
Price of manufacturing finished steel/cu. in.	0.00348	0.00352	0.00352	0.0048
Ratio: $\frac{\text{Price of fabricating Mg/cu. in.}}{\text{Price of fabricating steel/cu. in.}}$	6.6	10.0	9.1	4.9
Price of Mg wrought products if price of manufacturing were same as steel/lb.				0.28
Price of Mg wrought products to be equivalent to steel/lb.				0.146



United States production of magnesium extrusions, forgings, sheet and plate.

The magnesium alloys are not readily fabricated by cold working, but they are very readily worked at temperatures of 450 to 750 F. Magnesium fabrication requires equipment for preheating the sheet and for maintaining the dies and other working parts at suitable temperatures.

Commercially pure aluminum is one of the most readily formed of all the common metals. It is outstanding for the ease with which it can be drawn, spun, stamped, bent, or forged. In general, the higher the yield strength of the alloy and the lower its elongation, the more difficult the alloy is to fabricate. Values of yield strength and elongation depend not only upon the composition, but also upon the heat treatment. The common aluminum alloys are most readily fabricated in the annealed condition, while the heat-treated aluminum alloys are most readily fabricated immediately after quenching. Aluminum alloys are stronger at their working temperatures than steel is at its working temperature. As a result, about 25% heavier forging hammers, for example, are required to forge a given part in aluminum than is required to forge it in steel.

The machinability of the various alloys depends

Table 5—Comparison of Fabricating Costs of Aluminum and Steel

	1939	1946	Feb. 1947
Approx. composite price of common Al alloy sheet and extrusions/lb.	$0.346	$0.277	$0.277
Price of Al ingot/lb.	0.20	0.15	0.15
Price of manufacturing Al wrought products/lb.	0.146	0.127	0.127
Price of manufacturing Al wrought products/cu. in.	0.0146	0.0127	0.0127
Ratio: $\frac{\text{Price of manufacturing 1 cu. in. Al}}{\text{Price of manufacturing 1 cu. in. finished steel}}$	4.2	3.6	2.6
Price of Al wrought products if fabricating costs were same as for steel/lb.			0.21
Price of Al wrought products to be equivalent to steel/lb.			0.088

not only upon the base metal, but also upon the composition of the alloys and their heat treatment. All of the magnesium alloys have similar machining characteristics, excepting the magnesium plus 2% manganese alloy, which is slightly less machinable than the others.

There is a considerable variation in the machinability of the various aluminum-base alloys. Of the wrought-aluminum alloys, 11s especially designed for screw machine stock is the most machinable. Comparison of the relative machinability of magnesium, aluminum, brass, cast iron, and steel made on the basis of power consumption during the machining operation gives the following ratings:

Metal	*Relative Power Consumption*
Magnesium	1
Aluminum	1.5
Brass	1.5
Cast Iron	3
Steel	6

These ratings cannot be taken too seriously, however, since free-machining characteristics and the presence of hard spots play a predominant role in determining machining characteristics. There is, however, no question but that magnesium heads the list in machinability.

Table 6—Relative Properties of Various Common Structural Materials

		Tensile Properties				Fatigue			
	Sp. Gravity	Ultimate Str., psi.	Yield Str., psi.	% Elong.	Shear Str., psi.	Tensile Str., psi.	Shear Str., psi.	Young's Modulus, psi.	Shear Modulus psi.
Symbol	d	S_u	S_t		S_s	F_t	F_s	E	E_s
Mild steel	7.85	55,000	30,000	40	55,000	20,000	12,000	30,000,000	12,000,000
Low-alloy steel	7.85	75,000	50,000	25	75,000	45,000	30,000	30,000,000	12,000,000
High-alloy steel	7.85	170,000	150,000	6	90,000	100,000	60,000	29,000,000	12,000,000
355T6	2.68	35,000	25,000	3.5	30,000	8,500	5,000	10,300,000	3,850,000
24ST	2.77	68,000	46,000	20.0	41,000	18,000	12,000	10,300,000	3,850,000
AZ63-HTA	1.83	36,000	13,000	4.0	20,000	9,000	6,000	6,500,000	2,400,000
AZ61 (Wrought)	1.80	44,000	31,000	14.0	21,000	17,000	10,800	6,500,000	2,400,000
			20,500(comp.)						
Cast iron	7.20	30,000	20,000	0.0	30,000	10,000	10,000	12,000,000	5,000,000

Shape			Mild Steel	Low-Alloy Steel	High-Alloy Steel	355T6	24ST	AZ63	AZ61	C. I.
-	d	Relative weight at same volume	1	1	1	0.34	0.35	0.23	0.23	0.92
-	$\frac{S_u}{d}$	Relative static tensile strength for equal weight	1	1.35	3.1	1.8	3.5	2.8	3.6	0.6
-	$\frac{S_t}{d}$	Relative static yield strength for equal weight in tension or short-column compression	1	1.67	5.0	2.44	4.35	2.56	4.5 3.0(comp.)	0.36
-	$\frac{F_t}{d}$	Relative fatigue strength in compressive and tensile stresses for equal weight	1	2.25	5.0	1.24	2.54	1.93	3.72	0.55
Plate of fixed width	$\sqrt[3]{\frac{E}{d}}$	Relative stiffness in bending or in column fixed on 4 sides having equal weight	1	1	1	-	7.8	17.0	17.9	-
Plate of fixed width	$\sqrt[3]{\frac{d}{E}}$	Relative weight of sheet fixed on 4 sides having same resistance to buckling	1	1	1	-	0.51	0.39	0.38	-

Pinion hobbing machines are relied upon to produce steel gears and pinions used in various timing devices.

Machining Problems in Production of Industrial Timing Mechanisms

by **C. R. HORTON,** *Chief Engineer, The Macnick Co.*

THE PRODUCTION OF very small parts for assembly into such horological devices as type work watches and clocks is a highly specialized precision industry. This involves equipment that in some cases is the same as or resembles certain standard machines of the metalworking industries, and in other cases is a development of the watchmaking industry alone. There is another field for time-measuring devices, however, for which the mechanisms must be individually designed, and usually are required to actuate some instrument, as opposed to the simple visual indication of time on a dial. These are the industrial timing devices. They are found in drives for recording charts, in time bombs for exploding charges in mines and in oil wells, in parking meters, clocks for taxi meters, watchmen's clocks, and in a miscellaneous group that can best be classified as interval timers. In this last group are included all those devices in which a clock mechanism is used to initiate, repeat or continue any process at some predetermined or variable time rate. They can be used to turn up the heat in the home at a certain hour, or to switch a light on or off, or in an almost limitless variety of applications.

High accuracy on extremely small parts, a major requirement in timing devices, made necessary a number of refinements in machining to achieve mass production.

The output of the Macnick Company goes into this industrial timing field. About 90% of the chart drives for circular recording charts are produced in its plant; clocks for all the taximeters made in the United States are another part of its production. The first parking meter was made here in 1934.

While industrial timing mechanisms of this sort are not required to have the precision in time measurement expected of a fine watch, a great degree of accuracy is required. They must be sufficiently rugged to withstand vibration and other conditions found in a plant, and of a size capable of actuating another mechanism when the application requires. The equipment producing the parts usually consists of small sizes of standard machine tools or presses, with some borrowing of special machinery from the watch and clock industry. Whereas small gears for timing devices of the "dollar watch" type are usually stamped

Eleven automatic screw machines are used in this department of Macnick. Several modifications have been made to achieve faster production.

from sheet stock, all gears and pinions for these industrial timing devices are hobbed. These and other refinements in manufacture are used to insure the accuracy and ruggedness that the service demands.

Materials used are largely of three types, and standardization upon these three helps to keep down inventories. These are:

1. Leaded clock brass. This brass, containing about 2% lead, is free machining, punches cleanly, and has antifriction properties to a degree sufficient to make it useful for the simple bearings in the mechanism. The last-named property dictates its use for frames for the clockwork, as the small shafts can be mounted by simply drilling holes in the brass frame. Results have shown the brass to have a cost advantage over lower-priced materials, as the process of inserting a suitable bearing material in the frame made from a competing metal increases the cost beyond that of the all-brass frame.

2. B-1113 steel. All pinions are made of this steel. Pinion and shaft are usually integral, so the ends of the turned piece are polished and become the pivots concentric with the pitch.

3. Standard drill rod, of about 0.90% carbon content. When small parts must be hardened, this is the steel used.

All of the turned small parts made for timing mechanisms can be economically produced on automatic screw machines of Brown & Sharpe and Swiss makes. The Macnick Company makes most of its own cams, as do many companies using these automatic machines. A set of cams for a run on the machines can be made in about 3 to 4 hr. unless it involves factors of unusual difficulty. Cams are made of steel, or cast iron or of laminated plastic. Cams for the Swiss type of machine are not made in the factory. Meehanite is used for the latter.

One of the problems arising from the small size of the work is the difficulty of obtaining highest possible cutting speed. The free machining brass can be cut at very high rates, but the small size frequently makes this maximum unobtainable in a machine turning not more than 6,000 rpm.

In machining a pillar post in the automatic screw machine, a #56 drill, 0.046 in. in dia., was used to drill a hole afterwards tapped with a 0-80 tap. The work was done on a Brown & Sharpe No. 00 machine, with speeds up to 6,000 rpm.

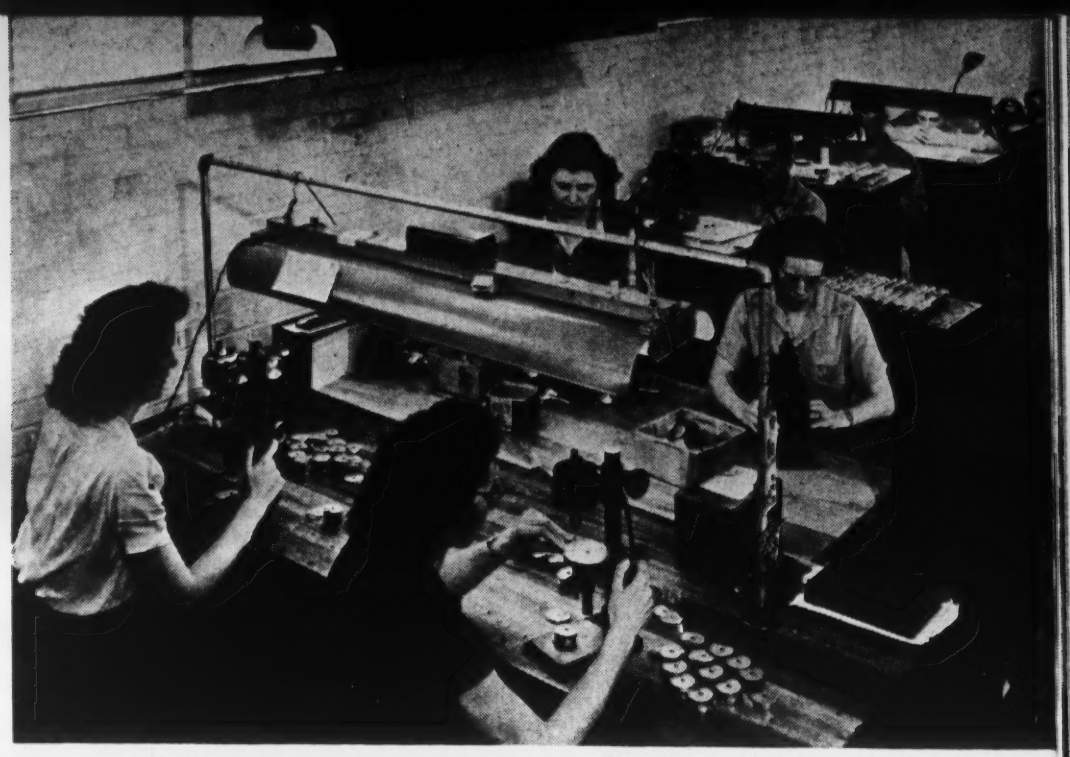
A solution worked out for small deep hole drilling was to add the standard turret drilling attachment for the B & S screw machine, so that the drill was rotated in the turret. By this means a relative speed of 8,000 rpm. and upwards was obtained for the drilling.

Although the saving in time was only one-third of a second per piece, the saving for the 400,000 pieces in the run was estimated at 11 days.

Polishing of a dial face in a speed lathe required the holding of a thin disk of metal in such a way that the entire surface could be reached with a piece of emery cloth wetted with oil-emery flour. After many trying experiences with various types of chucks a vacuum pump was connected to the drive of the machine. The disk is held against the bell, the lathe started, and manual pressure is maintained against the piece for about a second until the vacuum is obtained. The surface of the disk is then brightened with the abrasive, and the lathe is stopped. Loss of the vacuum permits the piece to drop from the bell into the hand of the operator. The entire operation requires only about 10 sec., and the edges of the disk are not crimped as was the case when the chuck was used.

Another modification of an existing machine, this time an automatic screw machine, saved an additional setup of the workpiece. A mainspring bushing 1 in. in dia. was designed to have two spanner holes, each ⅛ in., drilled in one end face to permit use of a wrench in assembly. The standard deburring attachment provided only one spindle. Rebuilding of the deburring attachment journals to accommodate two spindles made it possible to drill the two spanner holes simultaneously. This part is of the usual leaded commercial brass rod.

Broaching can be done on the screw machine by locking the spindle during the operation. Machining of a center wheel pinion for a clock movement required the broaching of a 1/16-in. square hole. Accuracy and economy made it desirable to perform the operation at the time the piece was made in the



Small sensitive drills are used to obtain the tiny accurate holes needed in watch plates.

automatic screw machine. The sequence of operations that proved most successful was as follows: (1) Three diameters cut with form cutter; (2) turn two additional diameters; (3) drill 0.067-in. hole; (4) stop spindle, lock with brake, broach 1/16-in. square hole with plain end broach, withdraw, release spindle brake; and (5) cut off.

A roller pin must be inserted into a balance wheel, and as the pin is impinged upon by the escape lever of the clock mechanism it is desirable that it be of steel hardened and polished. It is imperative that it be very firmly affixed to the balance wheel. The balance wheel is stamped from leaded clock brass, and is 0.050 in. in thickness. The pin is 0.027 in. in dia., and about 5/32 in. long. Attempts to obtain a firm drive fit in the brass stock failed, due in part to the small area of contact between the two parts.

The problem was finally solved by using standard drill rod for the 0.027-in. pin, cutting it to 5/32-in. lengths and pointing each piece, then heat treating to glass hardness and tumble polishing to a high degree. The pin is then set in a small die on a press, pointed end up, and the balance wheel is placed on the positioner. A quick stroke of the ram drives the hardened steel pin through the brass without the need for a pilot hole, and leaves the two parts firmly joined.

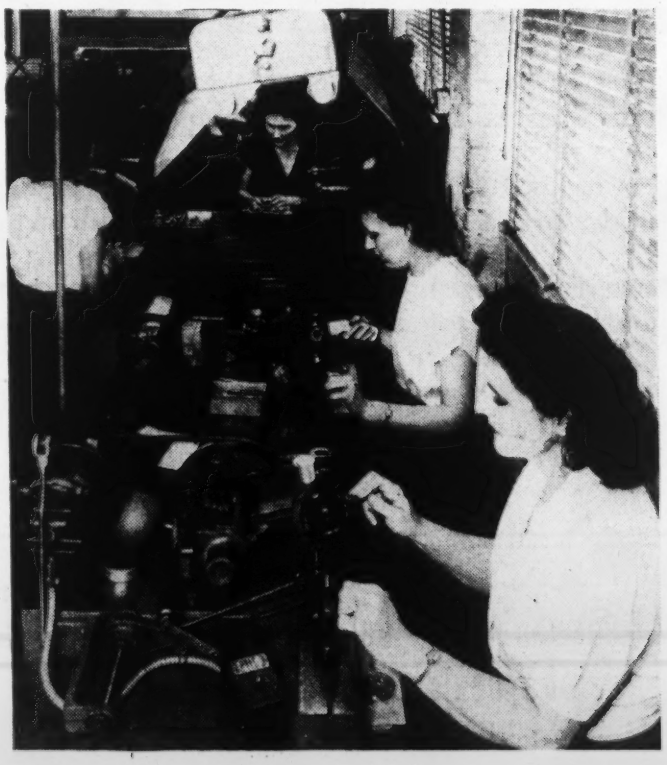
The stroke drives the pin through so that the balance wheel is flush on one side. The same procedure is used in installing the pallet pins in the fork or escape lever.

The use of the leaded clock brass itself as a bearing, with burnished ends on the shafts, has already been mentioned. This gives a satisfactorily low friction relationship, jeweled bearings in the frame being unsuitable because of susceptibility to shock. The burnishing of the steel shaft ends is done on a Swiss-type burnishing machine, using a carboloy burnishing wheel.

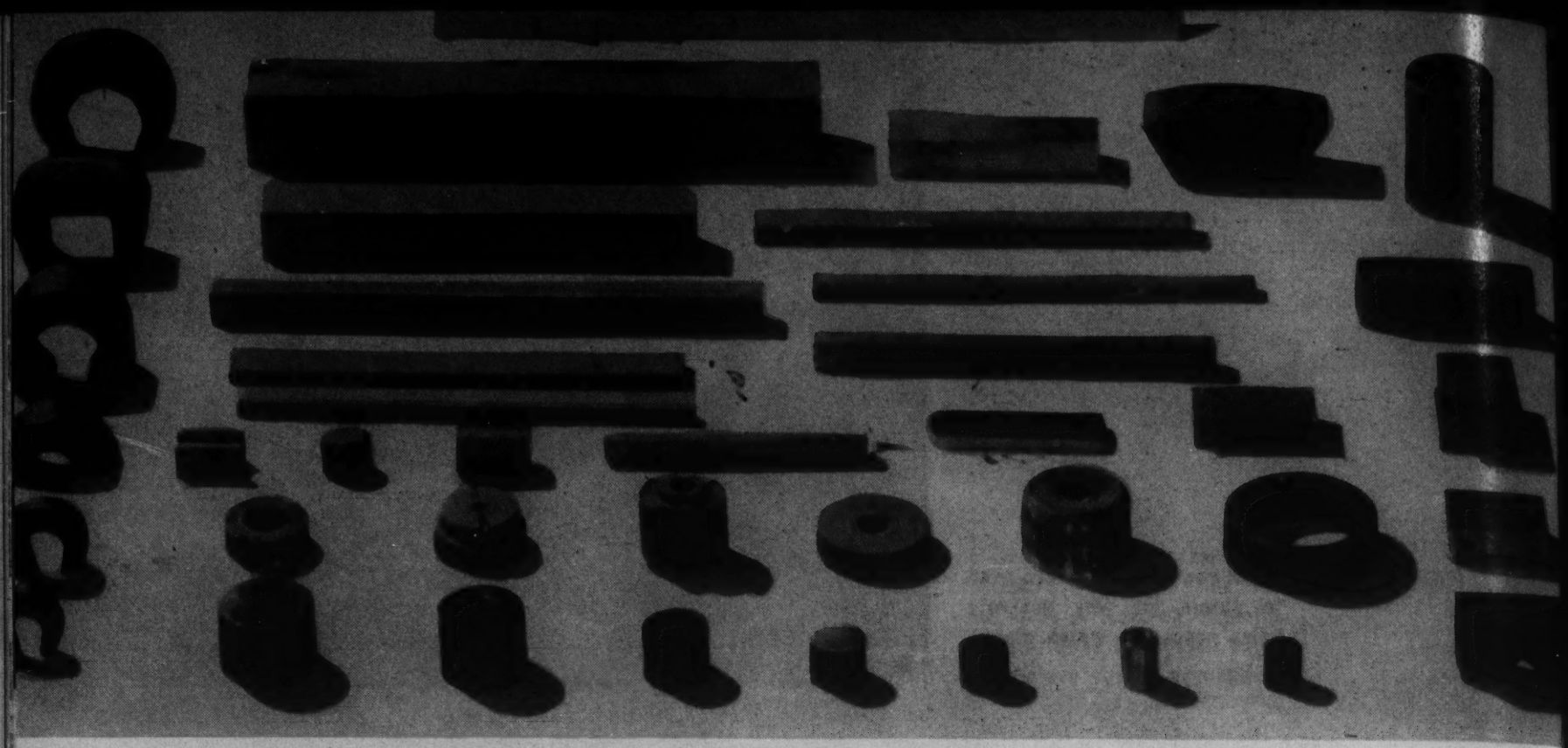
Small pivots of staffs are left 0.0004 to 0.0008 in. oversize in the original machining, and are placed in the burnishing machine in such a manner that the pivot rests in a notched Carboloy anvil. Both the burnishing wheel and the workpiece revolve in the machine, and are turned in opposite directions, so that they rotate upon each other. This helps to insure roundness of the burnished part. The wheel, 2-7/16 in. in dia., has no cutting edges, but is ground to a specified roughness, and with the grinding scratches having a helical angle of about 15 to 20 deg. on the face of the wheel. The diameter of the wheel gives it a differential motion over the surface of the pivot, and the diagonal scratches cause a slight shaving action to take place, removing excess metal as a dust.

Burnishing is done with the wheel wetted with oil, but without the use of an oil jet.

The entire plant is air conditioned, partly to insure freedom from dust particles in the clock mechanisms, and partly for the benefit of the employees, which in itself alone makes for higher quality. Heating is done with natural gas, so that fuel costs are low, but the power costs rise during the summer months as a result of the air conditioning.



The two foreign-type pivot burnishing machines shown in the foreground are copies made in this country during the war.



All of these shapes of alnico permanent magnets were produced by the sand casting method.

Modern Magnetic Materials

by **H. E. FINKE,** *Metallurgy Div., Chemical Dept., General Electric Co.*

SINCE THE DISCOVERY of the lodestone, the first permanent magnet, many centuries ago, man has been intrigued by the cause and effect of magnetism. Progress in this field has been slow until recent years when scientists and engineers, armed with modern technological and scientific tools, have made vast strides in discovering, developing and utilizing new magnetic materials. Five of the more recent magnetic materials—the alnicos, cunico, cunife, vectolite and silmanal—will be briefly covered in this article.

Alnico, probably the best known of the newer magnetic materials, was in limited use before World War II, found greatly increased use during the war and, where not already in use, is rapidly being adapted by design engineers to give more compact, stable, and satisfactory designs of electrical, mechanical and magnetic equipments.

Permanent magnet alloys, now available, can be designed to almost any shape, since with one or two exceptions they can be rolled, punched, machined or ground.

Cunico, cunife, vectolite and silmanal are less familiar to the majority of design engineers as their manufacture and use has not been so widespread as that of the various types of alnicos. These materials offer new solutions for some magnetic application problems that in the past have been considered impractical or impossible.

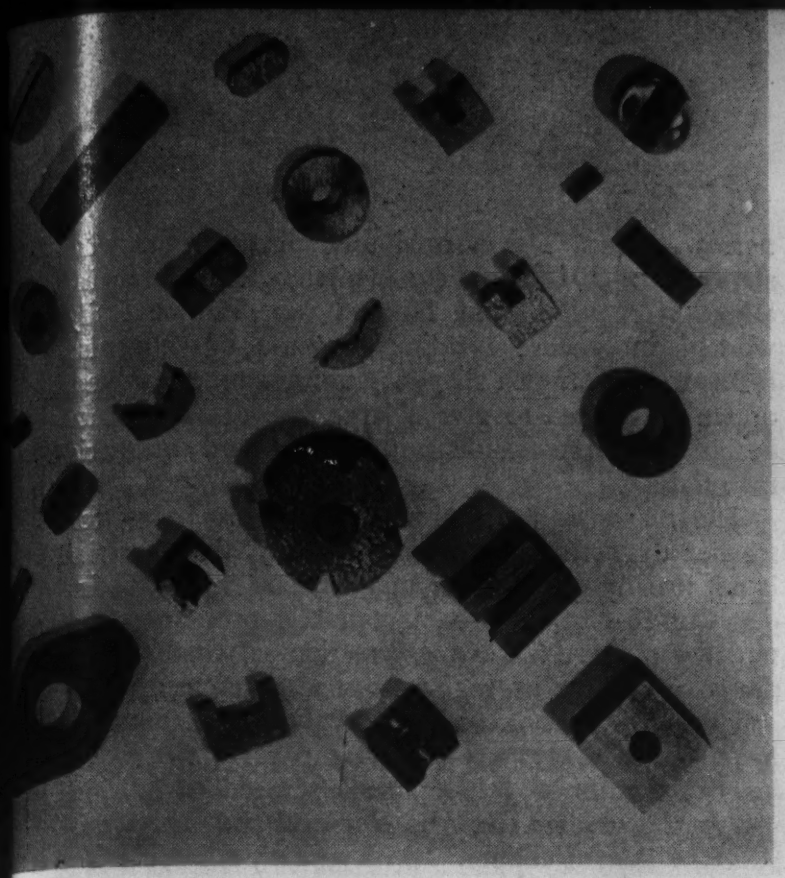
The Materials

A few generalities may help give us a better overall picture of modern magnetic materials:

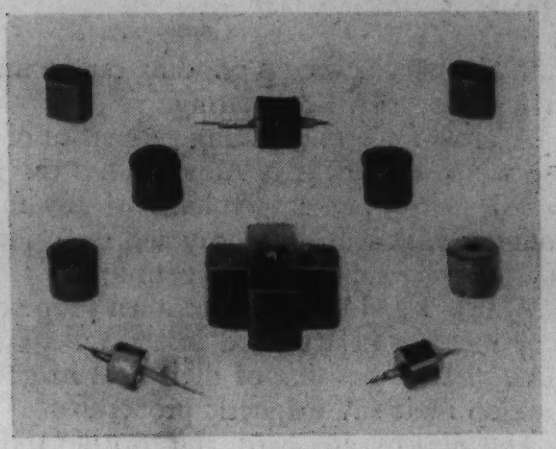
1. All of the materials, with the exception of vectolite, are precipitation hardening—that is, the high magnetic properties are dependent upon the crystalline precipitation of one or more of its constituents during manufacture.

2. With exception of the alnicos and vectolite, which can only be finished by grinding, these materials can be cold rolled, machined, punched, etc.

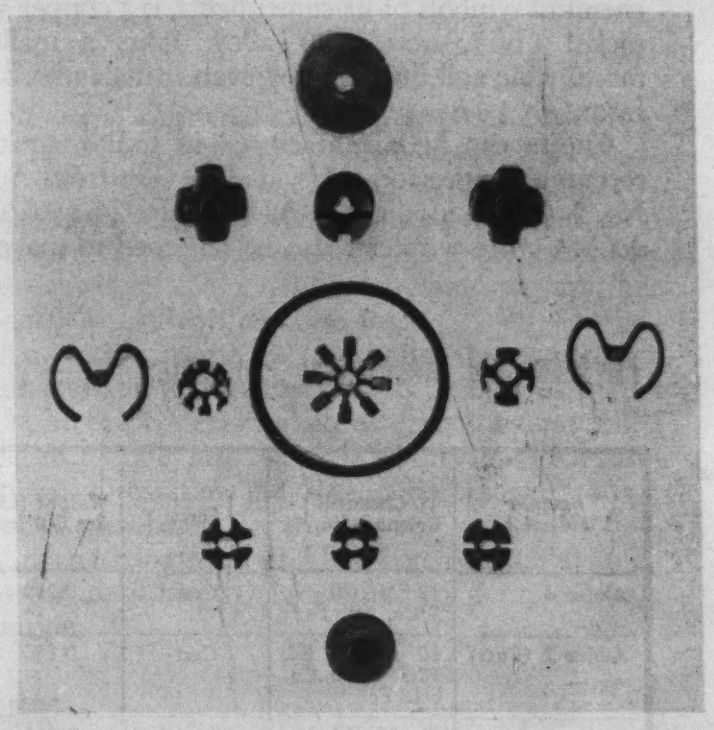
3. All the materials, with the exception of silmanal, have higher external energy values than the older



wide variety of shapes and sizes are possible, also, when sintered alnico is used.



Powder metallurgy was used to produce these Vectolite shapes. Lightness, stability and high electrical resistivity are features of Vectolite.



These Cunico magnets were punched from strip material before final heat treatment.

type chromium, carbon and tungsten steel magnet materials.

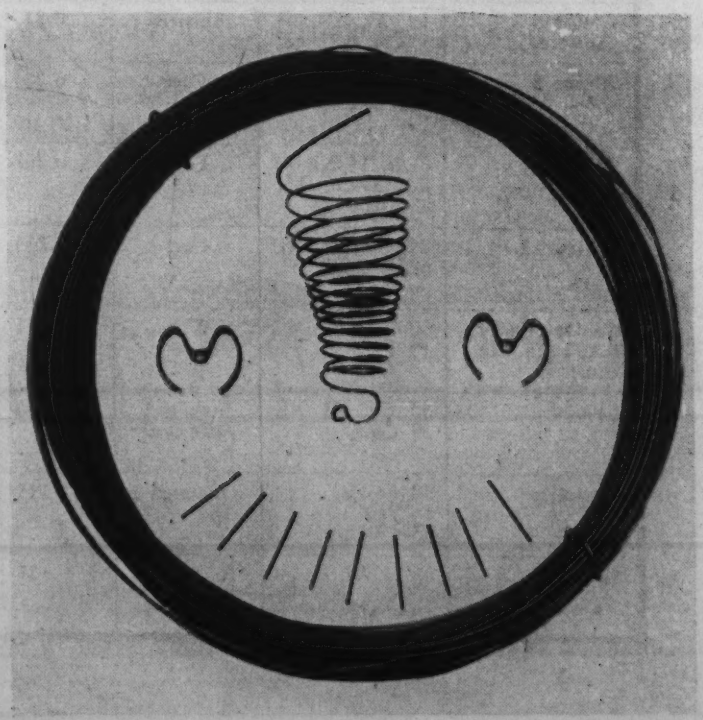
Table 1 lists the modern magnetic materials, giving the compositions, properties and commercial methods of fabrication of each.

The Alnicos

The alnicos are high-coercive force, high-energy magnetic alloys, the composition of which is mainly aluminum, nickel, cobalt and iron. The name, alnico, was derived from the chemical symbols, Al, Ni and Co, of the first three of these elements. There are seven commercially available grades of alnico, known as numbers 1, 2, 3, 4, 5, 6 and 12, each of which is of different composition and requiring a different heat treatment to bring out its particular magnetic properties. These seven grades provide a wide variety of materials from which the design engineer can choose the one best suited for any particular application.

Alnico magnets can be classified into two main groups—cast and sintered. The former are usually cast in baked sand molds, while the latter come under the heading of powder metallurgy materials. All seven grades of alnico can be cast, while alnico 2 and 4 comprise the bulk of sintered magnets, with alnico 2 being the most widely used. Limited quantities of sintered alnico 5 have been produced satisfactorily, but with slightly reduced properties, by the Metallurgy Div. of the Chemical Dept., General Electric Co.

Usually it is more economical to manufacture magnets under 15 or 20 grams in weight by the sintering process, while for heavier magnets the casting process is preferred. This is not always true; sometimes the higher mechanical properties of sintered magnets are necessary for heavy magnets, and sometimes light



The cunife magnets and stock shown here illustrate the ductility of this magnetic alloy.

castings that require no grinding can be manufactured at less cost than by sintering.

A few of the outstanding properties of the alnicos are worth noting here. Alnico 5 has the greatest external energy per unit volume of any magnet alloy commercially available today and is an ideal material for use where space is at a premium.

Alnico 5 and 6 have directional properties; that is, they must be heat treated in a magnetic field in the same direction as that of their final magnetization to develop their full magnetic properties.

The alnicos are hard and brittle alloys, can be finished only by grinding, and consequently should be cast as near to the finished dimensions of the part as is economically possible.

Cunife

Cunife, the name of which was derived from the chemical symbols of its constituents, is a copper (Cu), nickel (Ni), iron (Fe) alloy. It is a malleable, machinable and ductile alloy even in its age hardened form.

Cunife can be manufactured in round, square or rectangular wire form. Usual sizes vary from A.W.G. No. 2 (0.258 in. dia.) to A.W.G. No. 24 (0.0201 in. dia.). Cunife wire can also be flattened to make thin narrow shapes. The normal tolerances for the wire sizes are ± 0.001 in., but closer tolerances can be maintained if required. The finished wire can be easily worked in a wire bending machine or otherwise formed into complex shapes. Cunife can be punched, drawn or formed to give a large variety of intricate designs not practicable with other hard magnetic materials.

The magnetic properties of cunife are better for smaller diameter shapes. Consequently, this material is not usually specified for magnets larger than ¼ in. dia. Cunife has directional magnetic properties and must be magnetized in the direction in which it was drawn to obtain its high magnetic characteristics.

To completely magnetize cunife, a magnetizing force of 2,000 oersteds (4040 amp.-turns per in. of length) is required; it has a tensile strength of 120,000 psi. in the smaller sizes. Its electrical conductivity is 9.2% of that of copper.

Cunico

Cunico, the name of which was derived from the chemical symbols of its constituents, is a copper (Cu), nickel (Ni), cobalt (Co) alloy. This alloy is a ductile, malleable and machinable alloy and can be manufactured in a wider variety of forms than cunife.

Physical and Mechanical Properties

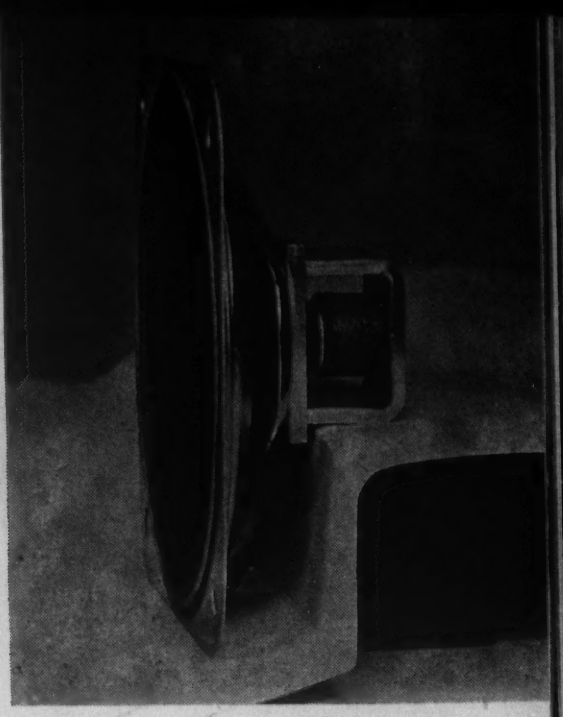
Magnet Material	Chemical Composition, %	Form	Weight (Lb. Per Cu. In.)	General Mechanical Properties	Transverse Modulus of Rupture (Lb. per Sq. In.)	Tensile Strength, Psi.	Hardness (Rockwell)	Mean Temp. Coefficient of Expansion (20 C to 300 C) x 10^6	Resistivity (Micro-Ohms per Cm. per Cm. at 25 C)
Alnico 1	12 Al, 20 Ni, 5 Co, bal. Fe	Cast	0.249	Hard brittle	13,900	4,100	C-45	12.6	75
Alnico 2 (Cast)	10 Al, 17 Ni, 12.5 Co, 6 Cu, bal. Fe	Cast	0.256	Hard brittle	7,200	3,000	C-45	12.4	65
Alnico 2 (Sintered)	10 Al, 17 Ni, 12.5 Co, 6 Cu, bal. Fe	Sintered	0.243	Hard	70,000	65,000	C-43	12.4	68
Alnico 3 (Cross Section Over ⅝ in. x ⅝ in.)	12 Al, 25 Ni, bal. Fe	Cast	0.249	Hard brittle	22,500	12,000	C-45	13.0	60
Alnico 4 (Cast)	12 Al, 28 Ni, 5 Co, bal. Fe	Cast	0.253	Hard brittle	24,000	9,100	C-45	13.1	75
Alnico 4 (Sintered)	12 Al, 28 Ni, 5 Co, bal. Fe	Sintered	0.232	Hard	85,000	60,000	C-42	13.1	68
Alnico 5	8 Al, 14 Ni, 24 Co, 3 Cu, bal. Fe	Cast	0.264	Hard brittle	10,500	5,450	C-50	11.3	47
Alnico 6	8 Al, 15 Ni, 24 Co, 3 Cu, 1¼ Ti, bal. Fe	Cast	0.268	Hard brittle	45,000	23,000	C-56	11.4	50
Alnico 12	35 Co, 18 Ni, 6 Al, 8 Ti, bal. Fe	Cast	0.264	Hard brittle	50,000	39,500	C-58	11.0	62
Cunife (Under 0.155 In. in Dia.)	60 Cu, 20 Ni, 20 Fe	Wire	0.311	Ductile malleable	—	120,000	B-73	14.0	22
Cunico	50 Cu, 21 Ni, 29 Co	Strip rod wire cast	0.300	Ductile malleable	—	85,000	B-95	14.0	32
Vectolite	30 Fe_2O_3, 44 Fe_3O_4, 26 Co_2O_3	Sintered	0.113	Low strength brittle	2,600	—	—	8.5	225 x 10^6
Silmanal	86.75 Ag, 8.8 Mn, 4.45 Al	Rod strip sheet	0.325	Workable	—	—	B-95	—	19

Cunico is manufactured in rod, strip and wire forms. Age hardening is the last step of its manufacture; therefore, cunico magnets are supplied to a customer in their finished form rather than as raw stock.

Cunico can be cast in relatively large sizes if required; however, in order to realize slightly better magnetic properties, the bulk of castings for cunico magnets are usually made 1/16 to 1 sq. in. in cross sectional area.

Magnets can be punched to any desired size from cunico strip between 0.060 in. and 5/16 in. thick. It is preferred that the width does not exceed approximately 2 in. as wider strips have a tendency to develop cracks during heat treatment. Cunico wire is manufactured in standard round wire A.W.G. sizes from No. 2 (0.258 in dia.) to No. 24 (0.0201 in. dia.) with normal tolerances of ±0.001 in. Closer tolerances can be maintained if necessary. The wire is also made in square or rectangular cross section and is readily machined, drawn or otherwise formed to shape.

Cunico, unlike cunife, is not magnetically directional; that is, it can be magnetized in any direction desired. In general, cunico is better suited for magnet applications where a large cross section is needed to produce the required total flux. Less length will be required due to its high coercive force. Cunico requires approximately 3200 oersteds (6470 ampere turns per in. or length) for complete magnetization.



One large use of permanent magnets is in radio speakers. Here a voice coil is wound on an aluminum base which moves in the field of an alnico 5 magnet.

Max. Permeability	Commercial Methods of Fabrication	Remarks
14	Cast grind	General purpose grade of cast alnico having good magnet qualities at reasonable cost
11	Cast grind	Better magnetic qualities than alnico 1 at slight additional cost
12	Sinter grind	For small or complicated shapes
12	Cast grind	Lowest cost grade of cast alnico commercially available
6	Cast grind	High coercive force grade of low cost alnico. Used where short magnets are required
6	Sinter grind	For small or complicated shapes
18	Cast grind	Highest external energy and residual flux alnico. Magnetically directional
11	Cast grind	Higher coercive force than alnico 5, with lower residual induction and external energy
4	Cast grind	Highest coercive force of alnicos. Should be cast to size as material is very difficult to work
8	Cold roll, machine punch	Good fabricating properties combined with magnetic hardness. Magnetically directional in direction of working
3.8	Cast cold roll, machine punch	Readily workable, high coercive force alloy
3	Sinter grind	High coercive force, low residual, high resistivity material. Light weight. Permits short magnets with long air gaps
1.11	Machine punch cold roll	Extremely high coercive force and permanency. Low residual and relatively high cost. Limited applicability for special purposes

Vectolite

Vectolite is a sintered magnetic material made from iron (ferric and ferrous) oxides and cobalt oxide. It is of very light weight, having a specific gravity approximately one-half that of other permanent magnet materials, and has a high electrical resistivity (approximately 225 x 10^6 micro-ohms per cm. per sq. cm.) and a high coercive force.

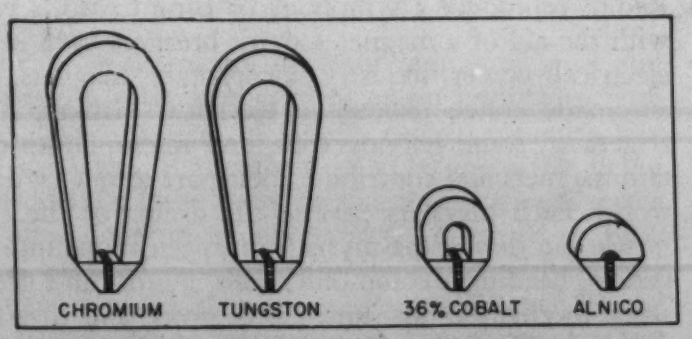
At the present time, the maximum size of vectolite manufactured is approximately 4 sq. in. in cross section and ¾ in. thick. Vectolite can be ground by use of the proper technique; however, it is an inherently mechanically weak material and should be sintered to size wherever possible.

A magnetizing force of 3,000 oersteds (6060 amp.-turns per in. of length) is required for complete magnetization.

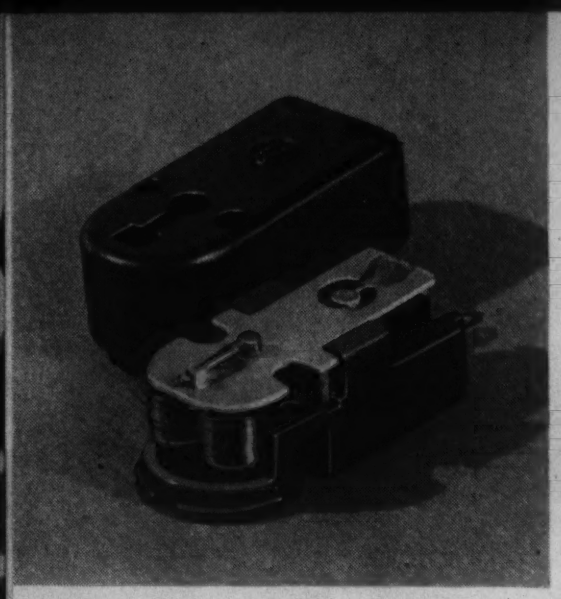
Silmanal

Silmanal, the name of which is derived from its constituents, is a silver (sil), manganese (man), aluminum (al) alloy. This material, because of its composition and heat treatment, is one of the most costly magnetic materials, but due to its extremely high resistance to demagnetization by magnetic fields, finds its rightful place among the newer magnetic materials.

Silmanal is ductile and malleable; it is as readily machinable as steel, and magnets can easily be made



All of these magnets have the same magnetic strength.



Phonograph pick-ups also rely on permanent magnets. Vibration on the needle moves a coil in the magnetic field, generating a varying voltage.

from cold-drawn wire, swaged-rod forms, or cold rolled sheets. A wide variety of magnet shapes can be made with very close tolerances.

Silmanal has a low residual flux and, therefore, the flux per unit area of the magnet is low. However, it has an extremely high coercive force. The intrinsic coercive force is over 6,000 oersteds and is thereby enabled to withstand severe demagnetizing effects. This high coercive force enables an extremely short magnet length to be used for a given air gap as compared with any other permanent magnet material.

Uses and Applications

The uses of permanent magnets are many and varied, but they can be divided into three basic categories, according to their function and operation. These are:

1. Attraction and repulsion.
2. Conversion of mechanical energy to electrical energy.
3. Conversion of electrical energy to mechanical energy.

In group 1 are snap action electrical switches, thermostats, magnetic gages, compasses, and many others.

Group 2 includes generators, magnetos, tachometers, phonograph pick-ups, and microphones.

Some of the items classified in Group 3 are motors, electrical instruments, and radio loudspeakers.

An idea of the vast number of uses for permanent magnets can be obtained from the fact that a magnet finds application in the speedometer and ammeter of an automobile, the magneto of an outboard motor, and most light aircraft. Your telephone requires a magnet. People who are hard of hearing increase their pleasure in life with the assistance of the magnet in their hearing aid. Radar, one of the world's recent developments, incorporates a permanent magnet. Radios reproduce a symphony or Bing Crosby's voice with the aid of a magnet. Circuit breakers used in the electrical power industry incorporate magnets. An automatic coffee maker, an electrical blanket, a refrigerator, some phonographs, and microphones contain magnets and contribute their part to our civilized world. Each plays its part in the drama of life.

We can divide the myriads of applications into six general headings: communications, motors and generators, mechanical instruments, controls, and toys and novelties. The scope of this article is such that it cannot cover the individual applications in detail, but the following lists, not complete by far, divided into general classifications, will give an idea of the present widespread use of the modern magnetic materials.

Communications:

- Electrical musical instruments
- Headsets
- Hearing aids
- Telephone receivers
- Loudspeakers
- Microphones
- Phonograph cutting heads
- Sound recording devices
- Telephone ringers

Motors and Generators:

- Generators
- Gyroscopes
- Magnetos
- Motors
- Rotary converters
- Selsyn motors
- Tachometer generators

Mechanical:

- Bulletin boards
- Chucks
- Clutches
- Door latches
- False teeth
- Holding blocks
- Knife holders
- Map markers
- Oil line filters
- Purse clasps
- Separators
- Signs
- Slug rejectors
- Stands
- Sweepers
- Tension devices
- Tool holders
- Tool retrievers
- Tools
- Tramp iron removers
- Weapon retrievers

Instruments:

- Ammeters
- Arc-back indicators
- Cardiograph recorders
- Cathode ray focusing devices
- Comparators
- Compasses
- Damping devices
- Float gages
- Flow meters
- Flux meters
- Frequency standards
- Galvonometers
- Liquid level indicators
- Mass spectrometers
- Medical instruments
- Meters on chargers
- Oscillographs
- Potentiometers
- Seismographs
- Speedometers
- Thickness gages
- Vacuum leak detectors
- Vibration pick-ups
- Voltmeters
- Watt-hour meters
- Light meters

Controls:

- Automatic controls
- Contactors
- Cut-out switches
- Governors
- Blowouts
- Polarized relays
- Pressure relief valves
- Refrigerator controls
- Regulators
- Snap action switches
- Thermostats

Toys and novelties:

- Building blocks
- Checkers
- Chessmen
- Dolls
- Fish pond games
- Float magnets
- Place card holders
- Toy dogs
- Toy trains
- Hand operated flashlights

Modern magnetic materials are contributing their part towards bringing comfort, accuracy, amusement, convenience, power and time to people in all walks of life in today's world. Each year brings many new applications and improvements of old ones. No one can foretell the future, but it is certain that modern magnetic materials will enable engineers and manufacturers to produce new products that will solve old problems and add a few pages to the history of modern scientific developments and the progress of civilization.

Combination quenching-forming machines; rather complicated in design, permit high production, close dimensional control and other economies in heat treating.

Ingenious Steel Quenching Practices Developed by Farm Implement Makers

by **KENNETH ROSE,** *Engineering Editor,* MATERIALS & METHODS

ONE OF THE COUNTRY'S oldest high production metalworking industries is that producing agricultural implements. Its progressiveness is attested by American leadership in both invention and production of farm equipment and, indirectly, by the great gains in mechanization of American agriculture. Agricultural machinery produced in this country is sold throughout the world and is copied in many countries that are attempting to increase the productivity of their own agricultural industry with implements of their own manufacture.

An industry antedating history might be expected to have associated with it many traditional methods, and tradition is frequently difficult to supplant by modern technology. The change to mass production methods for producing implements for mechanized agriculture, however, took place before the invention of the automobile and has progressed smoothly since.

While some of the heat treating traditions in the industry date back a hundred years or more to the first use of ferrous metal plows, present-day procedures are strictly modern and in accordance with best practice. The reconciling of tradition with modern metallurgical knowledge has produced some interesting heat treating procedures and equipment.

Especially noteworthy are some ingenious devices used to obtain precision or high production results without a heavy outlay for mechanical equipment. Some of these devices are shopmade. Most of them are exceedingly simple.

Simple Warpage Control Devices

At the John Deere Plow Works of Deere & Co., located at Moline, Ill., plow shares are pressure quenched to insure both the required physical properties in the steel and the proper contour of the piece. The pressure quenching device, a simple die deeply gridded to permit adequate water circulation around the plow share, is about 60 years old, but it performs satisfactorily in connection with modern heating equipment.

The plow shares are made of laminated steel and consist of a mild steel core faced on both sides with ⅛-in. layers of steel of 0.80% carbon content. The total thickness of the share is 5/16 in. After being formed in the forge shop the shares are brought to the heat-treat department where they are heated to 1700 F in a gas-fired Holcroft furnace. Upon withdrawing from the furnace, they are rough straightened by the heat treater. Hand straightening, consisting of a few

blows with a hammer, is usually sufficient. A small pneumatic press is available for die straightening if required. The leading edge of the share is then water-quenched by hand.

A rack holding two shares is attached to a pneumatic lift. The shares, which have been handled so quickly during the straightening and edge quenching that they have not cooled significantly, are placed in the rack and lowered into a brine bath, of about 10% salt content, maintained at room temperature. After 7 sec. immersion in the brine, during which time the temperature of the plowshares is lowered to between 500 and 700 F, the lift raises them. At this temperature the shares are still soft enough to permit a slight amount of contouring in the pressure quenching fixture. The shares are placed in the fixture and the fixture is closed, correcting any warpage that may have occurred in the shares during the prior treatment. The fixture is lowered into water, completing the quench and preventing any additional distortion.

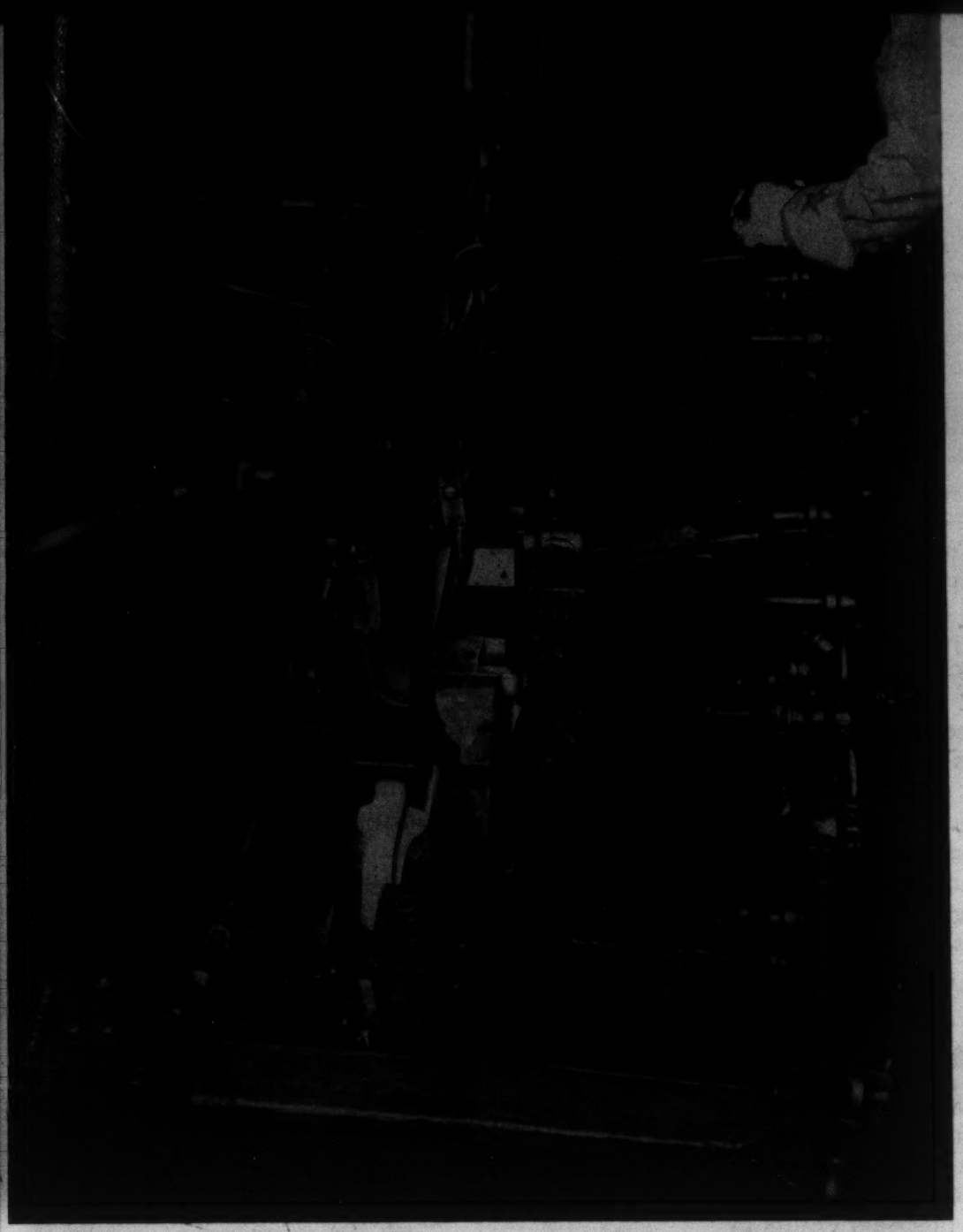
The plowshares at the conclusion of the heat treatment have a minimum surface hardness of 600 Brinell. The soft core increases the impact resistance of the shares.

The furnace in which the plowshares are heated is doughnut-shaped and has revolving holders in which the shares are held upright by supporting pins, thus providing uniform heating and greater accessibility.

Mold boards are heat treated in a somewhat similar manner. In these the material is a mild steel, with shims of 0.90% carbon steel forge-welded to both sides of the point. The boards are heated in a gas-fired furnace, also doughnut-shaped, in which the entire floor revolves. The boards themselves are held in an upright position by small alloy castings. Auto-

(Left)—A steering arm held in the jaws of an Urschel bending-quenching machine just prior to the bending operation.

(Right)—This view of the Urschel steering arm machine, with the jaws in the bending position and the work removed, shows the equipment required for carrying out the complicated bending operation.



(Left) — Combination forming-quenching machines, such as this Urschel axle stretcher, are high-cost, complicated machines but they permit substantial savings in forging and machining costs.

(Right) — This axle has been stretched by the Urschel axle stretcher to close dimensional tolerances that will be maintained in the subsequent quenching operation.

matic controls hold the temperature of the furnace within a narrow range. Upon being withdrawn from the furnace, the boards are treated by quenching the points in oil, then partially quenching the entire board in brine for 7 sec. The quench is interrupted while the metal is still hot enough to be slightly deformed without using excessive pressures, as in the case of the plowshares, is hand set if necessary, and then pressure quenched in water. Hardness at the point is required to be 600 Brinell minimum.

Automatic Device for Selective Hardening

An interesting hand-operated fixture is used to obtain high production in heat treating so called "soft shares." These shares are made of X1080 steel, and are left soft except for the points. A rotating frame with four radiating arms has been constructed of light angle iron and bar stock, and is pivoted upon a pneumatic lift. Each arm of the frame provides a rack in which 20 soft shares can be placed. Heating is

done in a lead bath held at 1500 F and quenching is done in an oil tank. Both lead bath and oil tank are open at the top.

One man operates the entire fixture, filling a rack on one of the arms, rotating the frame so that the arm is over the lead bath, and lowering by means of the pneumatic lift. The height of the lift is so adjusted that, after lowering, only the points of the shares are immersed in the molten lead. While the shares are being heated, the operator loads the next rack, and unloads the newly finished rack. About 2 min. is required for each operation. When heated, the lift is again used to raise the frame and rotate it to the next position, which brings the heated shares over the tank of quenching oil. Lowering the frame quenches the heated shares, and begins the heating cycle in the following frame. The next quarter-turn thus brings the quenched shares to the unloading station.

It has been found advantageous to provide four stations rather than three, so that loading and unloading may take place at different points. The slight disadvantage in requiring the operator to walk a few feet to the unloading station is offset by the simplified handling of treated and untreated shares.

Combination of Forming and Quenching

Form quenching is a much-used procedure at the Fort Wayne plant of International Harvester, Inc. At this plant, which makes heavy trucks, Urschel machines perform combined functions of forming and pressure quenching to obtain precision results in heat treated parts.

Front axles for heavy trucks, forged as I-beams with pads and bosses for mounting, are stretched, straightened and then pressure quenched, in an Urschel machine. Because of the difficulty of forging the I-beams to exact dimensions so that the kingpin bosses on the ends will be correctly located, engineers of the company have developed a procedure whereby the ends of the axle are die-forged and the center section is stretched to length at the time of heat treating. Lengths in the 5-ft. axles are held to 3/8-in. variation before machining, and the mounting pads must be held in a plane.

The axles, of 1046 steel, are heated in a Holcroft furnace, which has an automatic unloading feature to facilitate handling at the heat treat machine. The furnace is maintained at 1600 F. A simple hook operated over a block serves to carry the axle from the furnace to the Urschel machine.

When placed in the machine, horizontal clamping jaws first close upon the axle. Other jaws are next positioned against stretching lugs on the piece so that they may exert a force toward the extremities and stretch the center section to the length predetermined by the machine setting. End-dies are next brought against the kingpin bosses at the ends of the axle to maintain them in alignment during the quench. Arms then move vertically against the mounting pads to straighten them and maintain them in a plane during the quench. In the final forming operation the jaws bearing against the stretching lugs are moved to their expanded position, stretching the axle from 1/2 to 3/4 in., as required.

The forming operations require about 10 sec. The tank which surrounds the fixture is then flooded with water, quenching the steel as it is held in position by the various sets of jaws. After about 45 sec. the tank is drained and the axle is removed for checking in a gaging fixture. The entire cycle requires 70 sec.

Heat treatment is completed by 2 hr. in a draw furnace at 1050 F. The axles then have a hardness of 355 to 385 Brinell.

Another truck part that is form quenched in an Urschel machine is the steering arm. The steel used is 8640. The shape of the part is such that, starting from a forged straight rod with a boss at each end, the rod must be bent nearly double. The axes of the two bosses must be carried to a position at right angles to each other and in different planes.

The forged arms are heated to 1550 F in a furnace. As each is withdrawn, it is placed in one fixture of an Urschel machine that is mounted on a horizontal axle over an oil tank. The machine has two fixtures that are revolved around the axle so that one is forming a part while the other is quenching. The arm is held by clamps to maintain the alignment of four bosses during the forming and subsequent quenching of the work. The knuckle boss and tie rod boss are held and the arm is bent through an angle of nearly 180 deg. to bring the ends of the rod to their completed position. Two mounting bosses are also held in the required relationship to the remainder of the part.

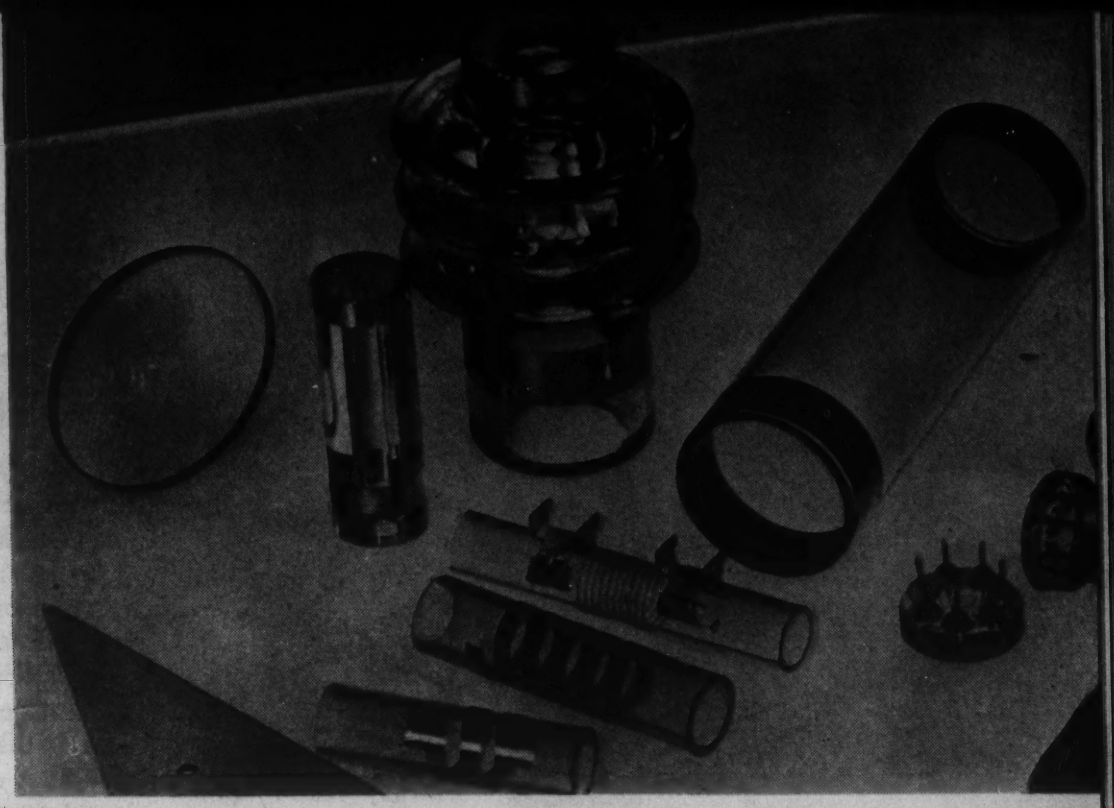
When the forming operation has been completed, the fixture revolves about its horizontal axis. The fixture and work are immersed in the oil bath and the second fixture is brought to the surface. This second fixture is loaded and operated while the first is completing the quenching part of the cycle.

A draw at about 1100 F completes the heat treating of the steering arms.

Reclaiming Warped Parts

Another heat treating operation at John Deere Plow Works illustrates the use of simple equipment that gives results. Harrow disks are made from 0.90% carbon steel that is formed hot. For hardening, the disks are heated to 1550 F in a furnace, removed with hand tools and placed on pins in an oil quench tank. When cooled to 200 to 300 F, they are immediately loaded into a continuous furnace held at 850 F for the draw. Occasionally some of the disks are warped slightly during heat treating. A simple procedure has been worked out that eliminates the need for expensive fixtures when reworking these warped disks. They are placed in a stack with two good disks at the top and two more at the bottom. Heavy weights are placed on the stack and the whole is run through the hardening furnace at 1550 F. After 20 min. at this heat the warped disks are found to have been pressed back into shape by the weights placed on the pile.

These reclaimed disks are then rehardened and drawn as before.



Metallized glass parts can be produced in a variety of shapes to permit flexibility of design and economical assembly.

Metallized Glass for Low Cost Joining of Glass to Metal

by **HAROLD G. VOGT,** *Corning Glass Works*

AS WITH MANY OTHER MATERIALS, it took a war to accelerate the application and to widen the acceptance of metallized glass. Although it had been developed some eight years before Pearl Harbor, metallized glass had limited commercial use until it went to work for the Army and Navy. In extensive service in electronics it provided hermetic sealing, visibility and an ability to withstand thermal shocks, some as severe as being suddenly plunged from 525 F into ice water. Its use is now expanding into a variety of peace time applications. Already it is doing a real job in many different industries.

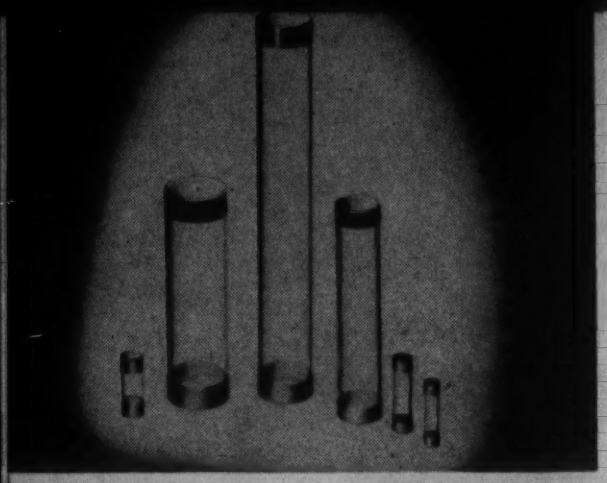
It is used to make instrument windows that can be sealed permanently and hermetically at low cost. These are now being used on electrical meters, viscosimeters, and pressure gages. Metallized glass is also used in applications such as trimmer capacitors, transformer bushings, and relay enclosures. An automobile maker could use this glass wedded to metals for dust-proof, moisture proof, crystal clear tail lights and parking lights. Makers of domestic household equipment could put perfect windows into stoves, washers or refrigerators, so that the housewife might observe what goes on inside.

The problem of achieving internal visibility and at the same time providing hermetic seals is greatly simplified through the use of metallized glasses.

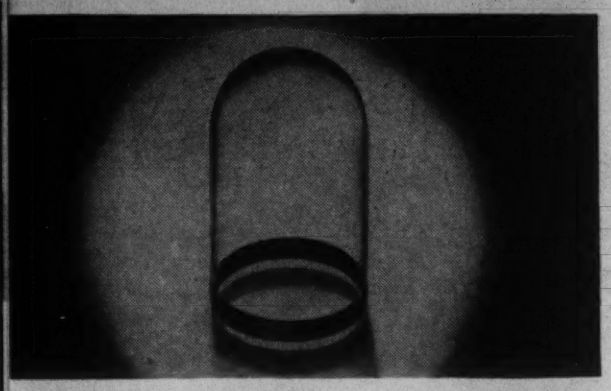
The bonding of glass to metal has always been an important but difficult job. Since the advent of the electric light bulb the industrial demand has been steadily increasing for a bonding of glass to metal that would give a strong, permanent seal that is not only liquid but also vacuum or hermetically tight. To produce a bond in which the forces are molecular and not just adhesive is an exacting task since glass and metals are so dissimilar. Glass is noncrystalline whereas metals are crystalline. Moreover, the newer low expansion types of glasses, which are desirable where unusual resistance to heat and heat shock are required, have expansion coefficients much smaller than those of ordinary metals.

Glass-Metal Bonding Methods

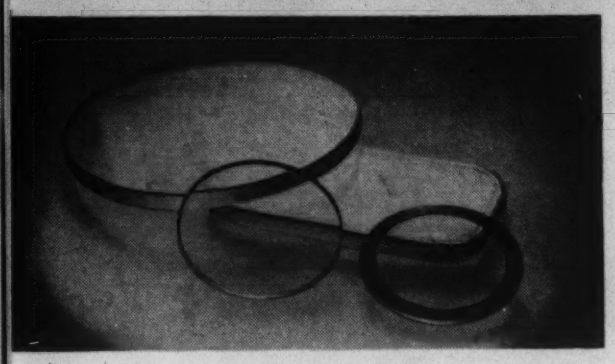
Much effort has been expended in trying various



The use of metallized glass tubes or rods produce assemblies of maximum strength and shock resistance.



Metallized parts such as this are used as hermetically sealed containers for electrical relays.



Certain types of metallized glass are available for low cost assembly of instrument windows.

methods of bonding but only two methods have been satisfactorily developed for mass production operation. They are fusion glass-metal seals and metallized glass-solder seals.

Fusion seals are required in glass-metal articles that have to undergo the rigorous high temperature degassing involved in making high vacuum enclosures and in those articles which are subjected to service temperatures higher than those possible with soldered seals. They are necessary for glass bulbs that enclose hot wires which would burn if any air leaked in. In fusion seals the expansions of metal and glass must be closely matched over the working range of temperature. Except for thin wire seals, this means that special metal alloys with non-linear expansion curves must be used. In large seals, the cost of the sealing metal becomes a factor for consideration. Moreover, fusion seals usually require costly and exacting glass-blowing techniques.

On the other hand, there are a great many articles of glass and metal that will not be subjected to extremely high temperatures and that can be designed so that the expansions do not have to be closely matched. Hence, there is the advantage that ordinary metals can be used. For such articles, Corning's metallized glass-solder seals offer new fabrication possibilities at low costs. Since metal parts can be soldered directly to metallized glass, the old cumbersome methods, which employed clamps, gaskets and cements, can be eliminated. It usually takes less than 1 min. to solder any one piece, and often there is an appreciable saving in assembly costs. Usually semi-skilled girls can do the soldering, using soft flame torches or induction heaters.

Characteristics of Metallized Glass

Metallized glass, Types A-1 and A-2, have a layer of metal attached by special processes in the glass plant so the manufacturer of the finished article can make permanent and vacuum tight seals to metal parts by conventional soldering methods. The metallized layer is applied at such elevated temperatures that it is bonded to the glass by molecular forces and becomes an integral part of the glass surface. The metallized layer usually consists of a noble metal, over which copper is plated, with a final coating of pure tin or solder. Although this composite coating is only about a thousandth of an in. thick, it is sufficiently tough for normal soldering to be done without excessive caution and it is wetted as easily as if it were solid copper. The finished seals have good mechanical strength. When seals are stressed to fracture, they show a tensile bond strength of 2,000 psi. Flakes of glass are often carried off by the metal part.

Glasses of a wide range of compositions, both high and low expansion, can be metallized. Therefore, good matches in expansions can be made with some glasses and some metals when it is necessary for special designs. However, particular thermal or electrical properties often dictate the choice of glass. Where mechanical stress or thermal shock in use is excessive, it is well to use tempered glass. Precision finished shapes are also furnished for special applications.

Soldering Techniques

For ordinary applications that will not have to operate at temperatures higher than 360 F the common lead-tin solders are suitable. For operating temperatures above 360 F lead-silver or tin-silver solders can be used. The choice of solder is largely determined by the applications. However, a solder with a melting point greater than 600 F should not be used. In some cases it is desirable to minimize assembly stresses and so low melting point solders, such as tin-bismuth or lead-bismuth, are to be used.

The fluxes on the market are generally satisfactory. Common fluxes which work well and which can easily be made up are a water solution of 72% zinc chloride, 28% ammonium chloride; a solution of zinc in dilute hydrochloric acid; and a solution of resin and alcohol. The last is useful where a non-corrosive flux is required as in electronic applications.

The tendency for the metallized layer to be dissolved in the molten solder increases with temperature so it is desirable to use solders of melting points as low as possible for any given application. It is equally desirable to avoid overheating and to minimize the time that the seal is held at high temperatures. A good way to prevent overheating the metallized layer is to carry the heat through the metal part and the solder to the metallized glass. Solder preforms are also of assistance. Metallized glass in practically all instances is supplied with a protective coating of

tin or solder on the metallized layer to aid in making the soldering simple and rapid.

Hand soldering with a temperature controlled soldering iron is quite feasible for small quantities of articles. A simple jig may be worthwhile. For semi-automatic equipment, soft air-gas flames can be used if the heating cycle is adjusted so as not to overheat the metallized layer. However, a low power, induction heater gives the neatest and quickest operation. Induction heating also has the advantage of securing good control of the heating rate and of giving good localization of the heating in the metal part.

Design Factors

In designing the glass-metal parts that are to be joined by soldering, there are two main considerations. First, it is highly desirable to minimize all stresses that occur when two materials of different expansions are bonded together rigidly and which expand and contract at different rates as the temperature changes. Second, since glasses are strong in compression, it is desirable to have any stresses present act compressively on the glass.

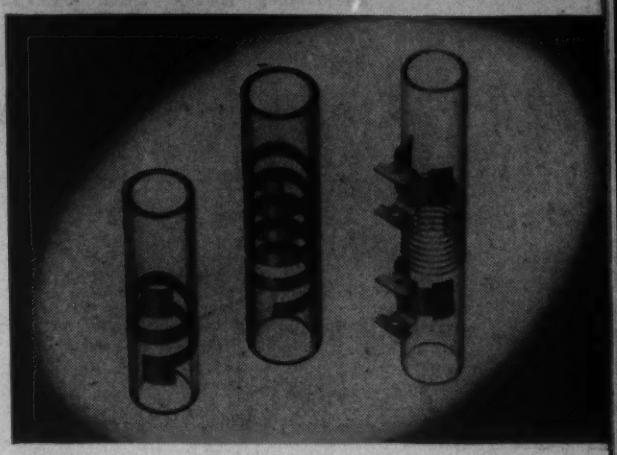
One of the best designs for the glass part is a tube or rod with the metallized layer in the form of a complete band at the end. Another is a disk metallized around the periphery. Flat or concave metallized surfaces are to be avoided unless the expansions of glass and metal are matched. In some instances low melting point solders must be used with flat surfaces. Bonding the glass and metal at isolated spots or over large flat areas tend to introduce troublesome shear stresses. The required thickness of the metallized layer varies directly with the value of the lowest temperature to which the seal will be subjected. For different applications there are different minimum areas of the metallized layers required to insure successful seals.

Satisfactory forms for the metal parts are annular rings or thin sheets with round holes or thin caps which can be sealed with good results on the outside of the end of a glass tube or rod. The greater the difference in the expansions of the glass and metal, the thinner the metal should be. In all designs, the metal should be as thin as is compatible with the necessary rigidity. For example, brass ferrules should range from 0.015 to 0.030 in. in gage thickness. The metal part should extend only up to within 1/8 or 1/16 in. of the edge of the metallized layer so as not to concentrate shear stresses at that boundary.

Applications of Metallized Glass Seals

Metallized glass tubes, of Type A-1 and A-2, are used to enclose resistors or other electronic components that require hermetic sealing. Special resistor tubes of tempered glass were made during the war. These tubes, with ferrules soldered, had to withstand 20 cycles of plunging from 525 F into ice water without glass failure and without the soldered seals developing leaks. Plain and skirted bushings have been soldered into metal cans to provide leak-proof and vacuum tight enclosures for electrical condensers or transformers.

Trimmer condensers require the higher strength bonds obtainable with Type A-2 metallized glass.



Dimensionally stable inductance coils and complicated coil forms can be made of metallized glass.

Here is an example of a completed assembly in which the metallized glass cover permits inspection of the inside parts.

Metallized glass parts are used for windows in electrical meters and in other instruments such as pressurized microwave apparatus.

Corning supplies several types of metallized glass for making sealed joints other than those required on extremely high vacuum applications. Type E is used to join metal fittings to the periphery of a window or on the end of a tube. A typical application is in gas meter windows. Type E allows simple joining at lower cost than do Types A-1 and A-2, particularly when large quantities are involved. However, Type A-2 has stronger bond strength and should be used for soldering iron lugs of the "saddle" design on tubes of glass. In one design of this type, iron lugs of 0.020 in. stock are soldered on a cylinder that has a spiral groove ground in the surface of the glass. Wire, soldered to the lugs and wound in the groove, is then held in precise alignment. Type A-2 is also used for joining metal to glass parts in trimmer condensers.

Types B-1 and B-2 are used to permanently fasten to glass surfaces metallized areas of fair conductivities that need not be held within narrow limits. A metallized area in the form of a spiral ribbon on a tube of low expansion glass may be used to provide an inductance coil. Since the ribbon is extremely thin and rigidly bonded to glass, which changes very little as the temperature changes, such induction coils are valuable for electronic applications involving ultra high frequencies. Wire can be soldered to the ends of the metallized ribbon. Where no soldering is required, the shape of the glass part is immaterial and the shape of the metallized area can be very intricate.

Barrel finishing is being used to deburr, burnish, hone and perform other finishing operations on large as well as small parts made of a wide variety of metals.

Manufacturing Economies Result from Barrel Finishing

by HERBERT CHASE

RAPID ADVANCES IN LABOR COSTS in recent years have made it essential for all volume producers in the metalworking industry to seek and utilize methods and equipment designed to lower costs. Those processes commonly grouped under the head of "finishing" have not escaped attention, for finishing costs are not inconsiderable and sometimes exceed the total of other prime costs.

Broadly speaking, finishing comprises most of the operations that follow machining or that type of machining done by cutting tools rather than by abrasives. It includes deburring, grinding, polishing, buffing and "coloring," as well as other mechanical processes for preparing the surface, in addition to coating the surface, whenever such coating is required.

One logical approach to cost reduction in preparing surfaces for finishing or smoothing them even when no applied finish is needed is to handle the parts in bulk rather than individually. This has long been done in barrel tumbling, but only in recent years have the possibilities of barrel finishing (excluding barrel plating) been given the thorough and scientific study they deserve.

Ordinary tumbling serves for certain classes of work but it is often crude and slow, lacking in proper control and not well adapted to precision machined parts, partly because impingements are likely to mar certain surfaces. However, not all work done in rotating barrel should be classed as tumbling.

Certain of the newer forms of barrel finishing are included in the term "Roto-Finishing." This type comprises grinding (for removal of burrs, tool marks, scale and the like); polishing or bright honing, which yields a smoother and brighter surface; and wet "coloring," which brings up a still higher luster. All of these are normally done wet, as the work is much more rapid than when done dry, but dry Roto-Finishing is carried on by some companies to burnish certain types of parts, especially those considered too fragile for the wet process, even though the dry processing time is much longer.

Roto-Finishing is not, strictly speaking, a "tumbling" process, as it avoids the impacts that are characteristic of most tumbling, even though it is done in what are ordinarily termed tumbling barrels. Parts are not carried to the top of the barrel and dropped against others as in some common forms of tumbling. The characteristic of wet Roto-Finishing is that the parts remain submerged in a mixture of stone chips, Roto-Finish compound and water. Parts are *not* thrown about because the mass, of which they are a part when submerged, rises only a few degrees as the octagonal barrel turns slowly and then slips back, without impacts between parts.

Thus, the action is what might be called "sloshing."

The Roto-finishing barrel at the right is being unloaded. When large parts such as the castings shown are deburred, they are lifted out so as not to drop on and mar other parts. The second barrel is being loaded.

It does produce, however, the desired relative motion between the chips and other abrasive and the parts. It is this motion, productive of a scouring action, that yields the desired results.

When deburring, the "breaking" or rounding of sharp edges, removal of tool marks or scale, or some combination of these are wanted, fast cutting abrasive and grinding stone chips (granite) are used. The more refined process of honing is done with softer stone (limestone) chips and a less abrasive compound. If burnishing is needed, steel balls or other metal particles are used with a non-abrasive compound, stone chips being omitted.

Under these methods of treatment, even parts machined to fractional thousandths of an in. are processed *without marring or any significant change in essential dimensions.* In fact, the process is exceptionally useful on such parts because, when fits must be close, it is of great importance that burrs be removed, as they are then most likely to give trouble in assembly. During the war, millions of aircraft engine and other high precision parts were deburred by Roto-Finishing with extremely large savings and a greater degree of uniformity than is attained in deburring by hand.

Whether grinding or honing is done in barrels by the methods here considered, the action is most pronounced on edges and convex surfaces. Edges can be merely "broken" (simply removing the burr or sharp edge) or can be considerably rounded. At the same time, of course, there is slight scouring of other exposed surfaces and of tool marks thereon, but the amount of metal removed on such surfaces is very slight or scarcely detectable unless the process is continued far longer than is commonly necessary.

Both male and female threads can be deburred in this way. In fact, the method is one of few if not the only economical way to fully deburr threads. Sharp crests are rounded slightly in so doing but there is no significant change in pitch. Similiarly, gear teeth can be deburred and, if they are not too rough, all burrs as well as tool marks on the teeth can be removed if the process continues long enough, yet the pitch and profile of teeth are not changed to any important degree.

Thus, in effect, the process acts selectively. It removes sharp edges and corners and produces more smoothing action on convex than on flat surfaces, although the latter do become smoother and even lose their tool marks if processed long enough.

During grinding or honing, the stone chips are also worn but they are kept from glazing by the abrasive compound that is added and which also does much of the cutting. It is necessary, of course, to use chips of such a size that they will not wedge in any holes or recesses that the pieces may contain. Large chips cut faster than small ones but do not

One of six small single-compartment barrels is being unloaded onto a screen supported by a chip pan. The latter has a drain for water used in hosing off chips and parts.

yield so smooth a surface as do smaller chips; hence the latter are chosen when maximum smoothness is required.

Besides changes in chip size and type and in the composition of compounds used, the chief variable is that of time of tumbling. If other factors are held constant, the harder and more abrasion resistant materials require longer tumbling than do those that are softer and more easily abraded.

The number of parts that can be handled in one barrel or one compartment varies, of course, with the size of the parts and of the compartment. For large castings or forgings, for example, it may be possible to process only one per compartment, though this is not often attempted. Several hundred small parts often are processed at a time.

Processing also has to be varied with the shape of the part as well as with the degree of initial roughness and the final smoothness required. As it is not easy to predict just which size of chip, type of compound, number of parts per charge and length of processing will yield the desired results at minimum cost, tests to determine optimum treating conditions are recommended.

In fact, the Sturgis Products Co., originators of Roto-Finishing, maintain an experimental setup for testing various products and reporting findings to prospective and present customers, and these facilities are now widely used, especially where the customer cannot well employ his own facilities for experimental work. Once the optimum conditions have been established for a given part, however, they should be recorded and always used in running this part.

Savings over hand burring, wheel grinding, polishing and buffing that are attained by Roto-Finishing vary through a wide range and depend upon many factors. Cases of record have shown savings of 90% or more down to only a few percent, but the average is high enough to have warranted many sizable installations of the equipment needed by companies which make thorough investigations of attainable economies before investing.

One of the largest of such installations is that in the new General Electric plant at Trenton, N. J., where automatic washing machines are now being manufactured. This installation includes 18 two-compartment octagonal barrels, each measuring 60 in. long and 27 in. across flats inside the wood lining. There are also six smaller single-compartment tilting barrels intended chiefly for small batches or for larger batches of very small parts. All barrels rotate at 20 to 22 rpm.

With each machine there are two swiveled hoist pans for loading chips and parts and for receiving the processed charge when it is ready for dumping. Each of these machines has its own supporting frame and motor drive through a reducer and button control. The larger machines are equipped with automatic timers that are set at the beginning of a run and stop the machine as soon as the time set elapses.

Of the 18 larger machines, three are arranged along each side of each of three short aisles and are served by electric trolley hoists for lifting the pans of chips and parts and discharging them into the barrels. After a barrel is loaded, the empty pans are placed one below each compartment, where it remains until the load is processed. Smaller barrels are of single compartment type and are equipped with smaller chip pans of somewhat different design, but all pans have drains so that parts and chips can be hosed off when dumped.

All pans also have supports for a screen onto which the load is dumped, as a rule, and chips are separated from the parts on the screen after hosing

off compound, which drains into a screen covered trench and sump where solid matter separates out before the water overflows into the sewer.

Stone chips remaining in the swivel pan are then shifted in the pan to a separating unit, where they are dumped into a hopper and thence are carried upward by a conveyor and dumped onto inclined mechanically agitated screens. Largest chips that do not pass the first screen of 1½-in. mesh slide down this screen into a chute and thence into a bin for this size. Others are caught similarly by screens of successively smaller size down to ⅛ in., and each size falls into its respective bin for reuse. At the bottom of the machine, particles broken from the stone are collected for disposal. This machine operates automatically, except for feeding the stone to it.

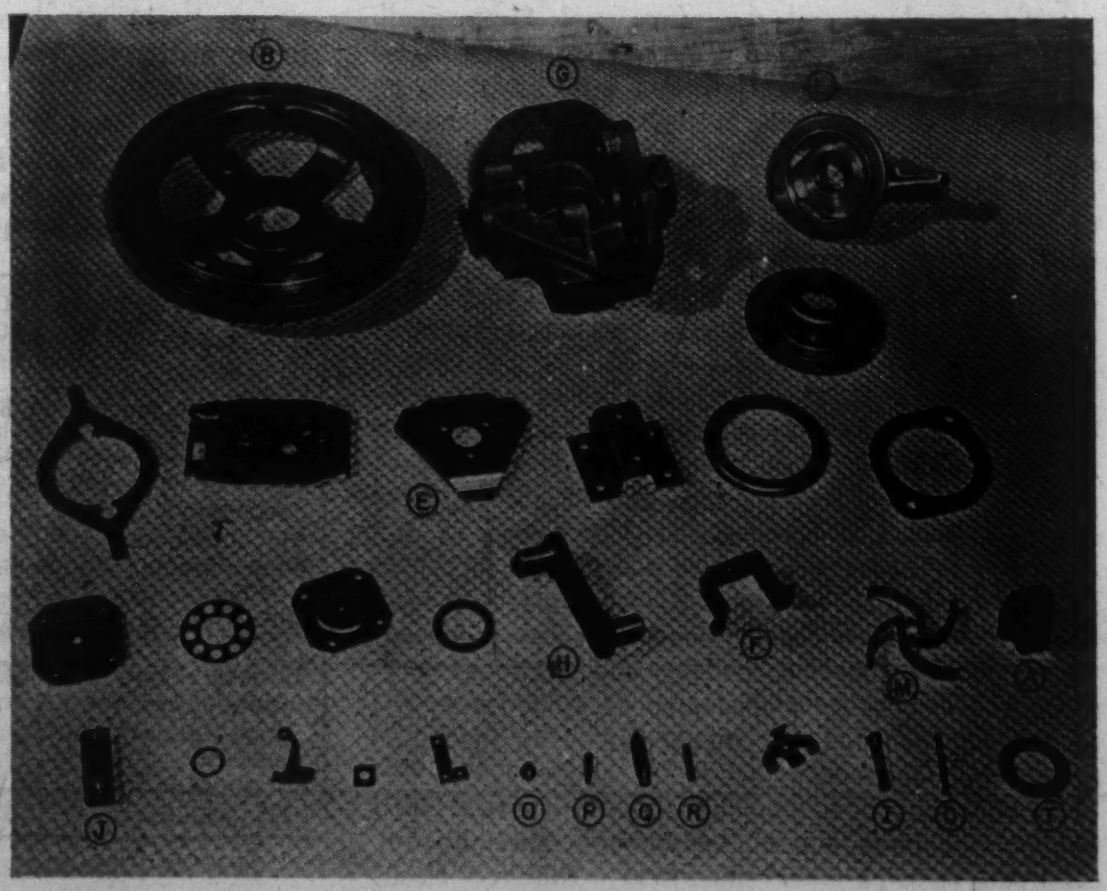
Parts of large size that might be injured by impingement on others if merely dumped from a processing barrel onto a screen are drawn from the barrel with a hook or rake, in which case the barrel can be flushed out and sometimes can be reloaded with new compound and parts without discharging the chips. Smaller parts usually can be dumped without injury by inching the barrel over slowly by use of an inching control button.

In the case of very small steel parts, separation from chips is greatly expedited by the use of a magnetic separator. This has a hopper at the top and a vibrated chute down which the mixture of chips and parts flow adjacent to a magnetized belt. As the belt turns and the load flows close to the belt, the steel parts are drawn out onto the belt and chips fall into a pan below. The belt runs over a pair of pullies and, just before it reaches the second pulley, the belt passes under a demagnetizer so that the parts

Machine used for magnetic separation of small steel parts from chips discarded from hopper into a vibrating chute.

fall off into a tote pan as the belt carries them over this pulley.

Parts of intermediate size and nonferrous parts of small size are separated on screens of such mesh that stones fall through when the load is raked across the screen and parts remaining on the screen are dumped into metal baskets. When loaded, the baskets are taken to an immersion washer where the load is given first a rinse in cold water and then one in hot water. This removes any foreign matter and alkaline not washed off in hosing at the barrel. Steel parts are given, after rinsing, a dip in hot soluble oil to prevent



All of these and many other parts used in the new G-E automatic washing machine are deburred by Roto-Finishing. Parts B, G and L are gray iron sand castings. A and M are aluminum die castings. H is a steel forging. O, P, Q and R are steel, and I brass screw machine products. T is a bronze and C a brass stamping. Nearly all remaining parts shown are steel stampings some of which are plated subsequently.

Table I—Time for Deburring by Roto-Finishing Parts for G-E Automatic Washing Machine

Name of Part and Type of Material	Letter Designation in Photo	Weight of Chips, Lb.	Size of Chips	Number or Weight of Parts per Compartment	Type and Weight of Compound	Time Required to Deburr, Hr.
Activator driver, aluminum die casting	A	700	5B	500 pc.	7 lb. No. 100	2½
Bearing flange, cast iron (6½ lb.)	B	700	3	4 pc.	7 lb. No. 11	1
Terminal strip brass stamping	C	150	5B	25 lb.	1 lb. No. 100	1½
Clutch cup, steel stamping	D	300 400	5A 3	50 pc.	7 lb. No. 11	2½
Spring stop, steel stamping	E	700	No. 3	150 lb. 500 pc.	7 lb. No. 11	1½
Suspension bracket, CR steel stamping	F	700	No. 3	450 pc.	7 lb. No. 11	3
Gear case, cast iron	G	700	No. 3	6 pc.	7 lb. No. 11	2
Link, steel forging	H	700	No. 3	300 pc.	7 lb. No. 11B	2
Manifold plug, tubular brass screw machine products	I	150	No. 4	500 pc.	1½ lb. No. 100	2
Hub clamp, strip steel 0.312-in. thick	J	700	No. 3	1000 pc.	7 lb. No. 11	1½
Gear, 40 teeth brass, 1⅜-in. dia. 0.81-in. thick	—	150	No. 5A	25 lb.	1½ lb. No. 100	2

rusting if they stand before any further processing or assembly.

There is a wide diversity in size and shape of the washing machine parts that undergo Roto-Finish operations. These parts include gray iron sand castings, aluminum die castings, steel forgings, screw machine products and stampings, and many small stamped and screw machine brass and bronze parts.

Up to the time this is written, Roto-Finishing in this plant is done only for burr removal and rounding of sharp edges, but it may later be extended to the bright honing or burnishing of some parts that now are wheel polished or buffed. In this event, limestone chips (already in extensive use elsewhere for bright honing work) will be required in addition to the grinding (granite) chips now employed for deburring.

Data on the time required for deburring, operations on several parts of different materials and sizes are given in the accompanying Table I, which also gives the weight of charge, size and weight of chips and type of compound employed. The weight of the latter commonly used is 1 lb. for each 100 lb. of chips. No. 100 compound is for nonferrous parts and No. 11 for cast iron and steel parts. Chip size is varied partly to avoid lodging in holes and partly to vary the speed of cutting and degree of smoothness attained. Small chips cut more slowly but yield a smoother finish.

Management of the plant, though sceptical initially of the process being satisfactory, especially for deburring large parts and those held within very close dimensions, has found that it gives satisfaction in these as in other cases and is well pleased with results secured.

Table II gives some data obtained from another plant on cost savings in bright honing certain parts by the Roto-Finish process, using limestone chips, as compared with wheel polishing and buffing preliminary to plating.

Table II—Saving Effected by Roto-Finish Bright Honing Over Buffing on Fishing Reel Parts, Labor Only

Type and Material of Part	Labor Cost per 100 Parts, Cents		Saving, Cents per 100	Per Cent Reduction in Labor Costs
	Buffing	Roto-Finishing		
Brass bushing, tapped screw machine production	34.4	1.3	33.1	96
Brass stamping, U-shape section	141.2	3.9	137.3	97
Star wheel, nickel silver	277.5	95.2	180.3	65.7
Assembly of brass stamping and two screw machine products	216.4	24.7	191.7	89
Circular plate with hole, stainless steel	23.1	21.0	2.1	9

Data gathered at The Shakespeare Co.

Mechanical tests on iron powder test specimens seldom give a true picture as to the ability of similarly produced parts to perform satisfactorily.

How to Evaluate Engineering Properties of Iron Powder Parts

by **ALEXANDER SQUIRE,** *Materials Engineer, Westinghouse Electric Corp.*

THE POWDER METALLURGY METHOD for producing small finished machine parts in large quantities at low cost has been given wide-spread attention. The advantages of powder metallurgy have been emphasized but little information has been offered regarding the engineering properties of the compacts.

There are several reasons for this lack of information. The major items of production have been porous bearings in which the tensile properties, resistance to impact or shear strength have little meaning. The factors involved in forming powdered metal parts (powder characteristics, forming pressure, sintering cycle, atmosphere control and subsequent operations) are very complex and methods used to produce parts of one shape with certain desired mechanical properties may not be suitable for producing another part of different configuration to meet the same mechanical requirements. The relative dimensions, positions of core rods, changes in cross-sectional thickness and the material from which the part is to be made have important bearing in this respect.

In preparing specifications for procurement of powdered metal compacts it is necessary to know what mechanical properties are desirable, what properties can be obtained, with what accuracy the properties can be determined, and how adequate acceptance tests can be devised. Unfortunately, almost all machine parts that are suitable for powdered metal production are either small or of irregular shape so that standard tests cannot be applied to specimens machined from them. Special test bars processed in a manner identical with the parts sometimes give an indication of the properties which may be expected, but for purposes of quality control the tests must be applied to the parts themselves. These tests must give a true indication of the mechanical properties of the compacts.

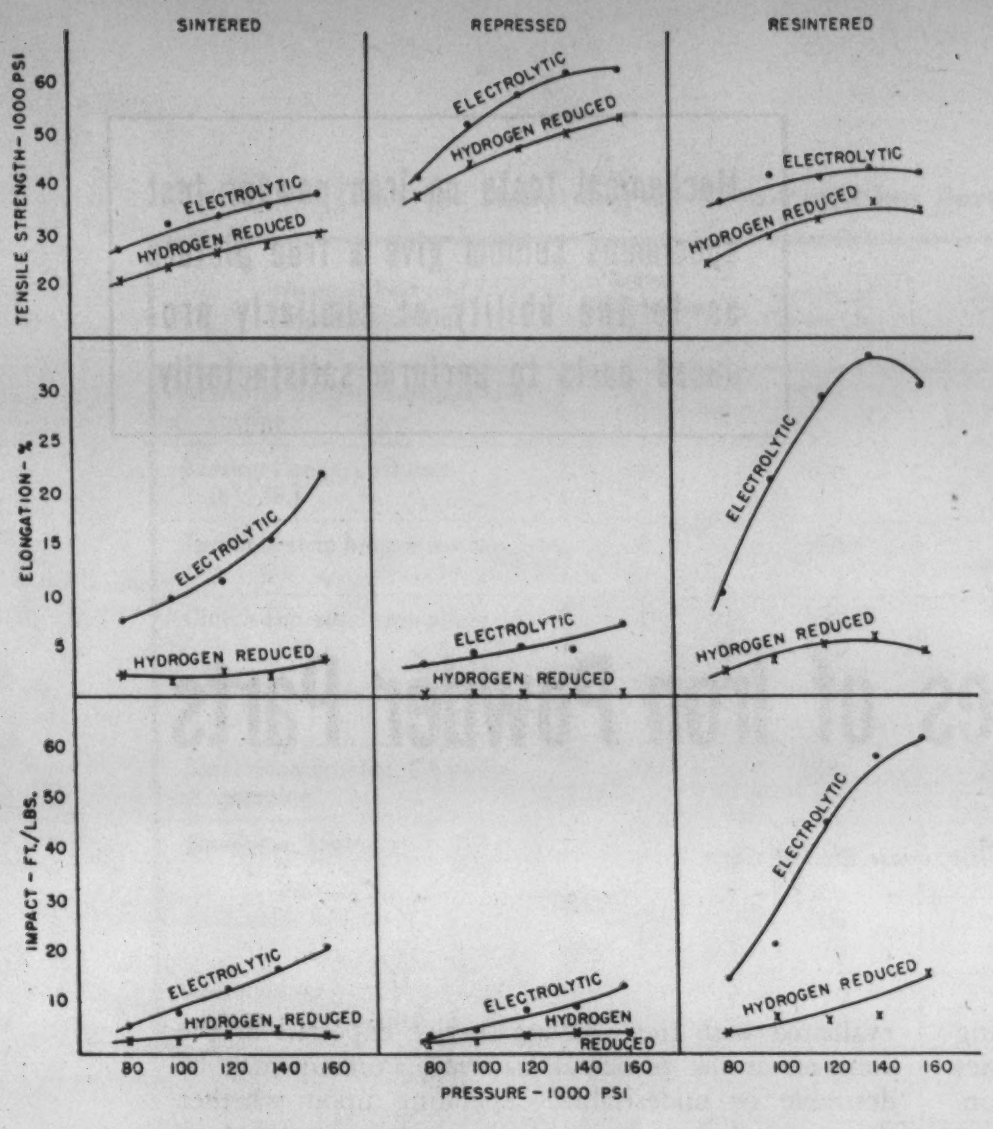
Quality Characteristics of Powdered Metal Compacts

The quality of a powdered metal compact must be evaluated with the ultimate service expected of the compact as the principal criterion. Porosity may be desirable or undesirable, depending upon whether the material is to be used as a bearing member or a structural machine part and, similarly, high shear strength can be sought for or avoided, depending upon the function of the part. Because of functional differences such as this, the quality characteristics of powdered metal compacts cannot be truly appraised without due regard for their design and end use.

It is considered desirable, whenever possible, to know the yield strength, tensile strength, elongation, and reduction of area of engineering materials. Knowledge of these values provides a basis for comparison of powdered metal compacts with the material from which similar parts have previously been made. Most parts made from powders are far too small for tensile specimens to be machined from them and the tensile test cannot be applied. Special test bars pressed from the same batch of powder as the subject parts cannot be used for purposes of quality control but have a distinct value in establishing adequate tests for such control.

Powdered metal parts, in general, have low resistance to impact and for this reason have failed in some applications. Standard notched or un-notched impact specimens can seldom be prepared from finished compacts, but modified impact tests can almost always be applied to the parts to determine uniformity of product. The range of impact strength can be determined by thorough testing of a specified number of qualification samples. Before specifying a low limit, the function of the compact in the structure of which it is a component should be ascertained and the possible impact which may be imposed upon the part investigated. Care must be taken to test the section that will be subject to impact stresses in service and, further, to test the weakest portion of that section.

The value of a bend test in quality control of powdered metal parts has several aspects. The test



Relationship between pressing pressures and physical properties in iron powder compacts.

may be applied to many finished parts; it may be destructive or non-destructive; it may be used to test for rigidity, elasticity, ductility or strength under load. It is rapid and simple.

Special fixtures are almost always required for the useful application of the bend test to finished powdered metal compacts and, as in impact test, it should be emphasized that the bend values themselves have little importance aside from their use in quality control. Numerical results of bend tests performed on compacts of different design cannot be justly compared because of stress concentrations set up within the parts by these differences in design.

The shear strength of powdered metal compacts is an important quality characteristic since most powder parts are soft and, consequently, may have low shear strength. The shear test is generally quite sensitive in the detection of low quality material and it is easy to apply to finished parts of almost any shape or size. The principal disadvantage is that only the strength of the section of the compact immediately tested in shear is determined, and care must be exercised in deciding which portion of the compact is most likely to fail in shear under service conditions.

The density and porosity of powder compacts are of great importance since other quality characteristics are very much affected by variations in porosity. It is of even greater importance that the distribution of porosity through a compact be as uniform as possible since lack of uniformity results in a corresponding lack of uniformity in mechanical properties.

Metal powder compacts of irregular shape with small projections or variations in thickness are likely to have a section of low density near the origin of irregularity.

The overall density and porosity of a part can usually be determined by simple gravimetric methods but such measurements do not reveal variations of density within a single piece. An accurate appraisal of the number and degree of density irregularities can be made by X-ray techniques. Density variations in the powder compacts appear as variations in film density. The accuracy of the method is limited only

Table I—Physical Characteristics of Iron Powders Used in Determining the Influence of Processing Conditions

		Percent by Weight	
		Electrolytic	Hydrogen Reduced
Chemical Analysis:	C	0.10	0.02
	Mn	0.18	0.34
	Si	0.04	0.20
	S	0.02	0.009
	P	0.01	0.007
	Ni	0.05	0.06
	Cr	0.17	0.04
	O_2	0.59	1.29
Screen Analysis:	+100	1.6	2.6
	—100	10.1	16.8
	—140	29.3	36.8
	—200	9.7	9.9
	—270	11.6	13.0
	—325	37.5	21.0
Apparent Density, gms./cc.		2.53	2.34
Specific Surface Area, $cm.^2/g.$		585	362
Rate of Flow, gms./sec.		1.28	1.36

by the uniformity of the X-ray film emulsion and the error introduced in reading the film density by means of a commercial densitometer.

An evaluation of the distribution of porosity throughout a powdered metal compact need not be made on each lot of manufactured parts since, in the mass production of powder parts, porosity irregularities or freedom from irregularities once determined can be expected in all subsequent units.

The porosity generally found in powder compacts is either inter-connected or isolated. The inter-connected type of porosity is usually so made, intentionally, to permit lubricants to penetrate the interior of the compact and to be later excreted. This porosity is found principally in porous bearings. Isolated porosity is to be expected more often in structural machine parts and in the stronger and more dense powder parts. Compacts with high or with interconnected porosity should be impregnated with a rust preventive to prevent the drawing of moisture into the pores by capillary action and consequent corrosion and failure. Many powder parts corrode rapidly because of the large surface area caused by their porous condition.

Little difficulty is experienced in producing structural powdered metal parts within an accuracy of 0.001 in. per in. normal to the direction of pressing and 0.005 in. per in. in the direction of pressing. If greater accuracy is required it may, in some instances, be obtained by grinding to the desired dimensions after sintering. As in all production processes, close tolerances cause high costs.

Hardness measurements on powder parts are usually so erratic as to be almost meaningless. In isolated cases, as in hardened steel powder compacts, hardness may be a useful criterion but, as a general rule, it should not be considered a determining quality characteristic.

The chemical composition of powdered metal compacts is sometimes a necessary quality characteristic but usually can be neglected as long as the parts pass physical tests. Difficulty is usually encountered in producing high grade compacts from low grade powder, but there is nothing to be gained in penalizing any manufacturer who is able to produce parts with desired properties from low grade powder.

Chemical control is desirable if the producer uses additives in the production of ferrous base compacts since the addition of certain elements would increase density and yet leave porosity at an undesirably high level.

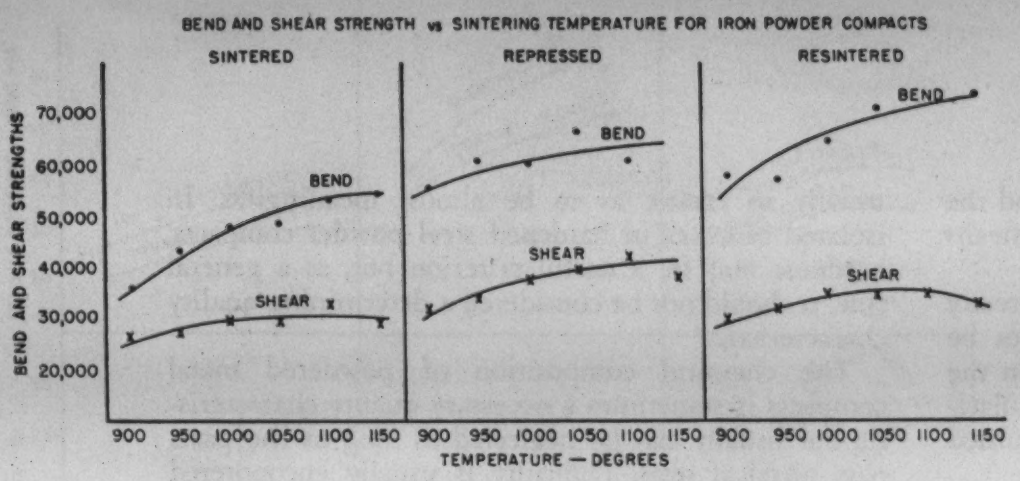
Influence of Material and Processing Conditions

A general survey of the effect of powder properties and processing methods upon the tensile strength of compacts produced from commercial iron powders has been presented by many writers. The superiority of the more chemically pure materials is apparent, and improvement in the strength of an electrolytic powder by increased compacting pressure and sintering temperature is noted. Subjecting compacts to additional operations such as repressing and resintering likewise results in improved strength.

To obtain more complete information regarding

TABLE II—Effect of Processing Conditions on Quality Characteristics of Iron Powder Compacts

Characteristic	Increase in Forming Pressure	Increase in Sintering Temperature or Time	Repressing	Resintering
A. Tensile				
1. Strength	Increase	Increase	Increase	Higher than after sintering but lower than after repressing
2. Elongation	Increase	Increase	Lower than after sintering	Marked increase
B. Impact				
1. Strength	Increase	Increase	Lower than after sintering	Higher than after sintering
C. Bending				
1. Strength	Increase	Increase	Higher than after sintering	Higher than after sintering but lower than after repressing
2. Angle	Increase	Increase	Decrease	Marked increase
D. Shear	Increase	Increase	Increase	Higher than after sintering but lower than after repressing
E. Porosity	Decrease	Decrease for low forming pressure. Increase for high forming pressure	Decrease	Same as for increase in sintering temperature
F. Dimensional Accuracy	Increase within limits	Decrease	Increase	Higher than after sintering but lower than after repressing
G. Hardness	Increase	Dependent upon chemistry of the material	Increase	Decrease, as a general rule
H. Chemistry	No change apart from reduction of oxides and diffusion of constituents			



Bend and shear strength tests are useful in detecting changes in sintering practice.

the influence of material and processing conditions upon the quality characteristics of iron compacts, two typical powders were processed according to various schedules. The first of these commercial powders was made by electrolysis and the second by reduction of mill scale in a hydrogen atmosphere.

The quality characteristics of the compacts produced from the higher grade material were superior in every respect and outstandingly so in elongation and impact strength. The impact strengths of electrolytic iron compacts are reasonably high whereas those of the hydrogen reduced iron are low even after resintering. These results indicate that compacts of moderate impact can be obtained by the simple pressing and sintering of electrolytic powder or by the complex processing of lower grade material. The same situation is true for elongation and tensile strength. Repressed hydrogen-reduced iron compacts have no detectable ductility, but the corresponding compacts formed from electrolytic powder have sufficient ductility to prevent brittle fracture.

Uniformity of Properties

The mechanical properties of powdered metal compacts are dependent upon the material and the method of processing. Since such relationships exist, it is important that when specifying limiting values for mechanical properties, sufficient cognizance be given the unavoidable variables and the range of the variables.

A certain amount of non-uniformity of properties is encountered because of variables in pressing. Porosity values of individual bars pressed under identical conditions may vary as much as ± 10%. In commercial furnace sintering of large numbers of pieces, sintering temperatures and atmospheres may vary and, as a consequence, other variables are introduced. Account must be taken of these variables and due allowance made for a certain degree of deviation of required physical properties from the mean. The degree of such allowance should be determined during the examination of qualification samples of a proposed structural component. Typical variations in the values of some quality characteristics are shown in Table III in which is recorded the ranges of results obtained in subjecting ten compacts to each of the indicated tests.

The tensile properties are the most reproducible of all the quality characteristics tested and the bend strength of resintered compacts the most undependable. It is considered that the bend strength results were influenced somewhat by the angle through which the bars were bent since the results obtained using repressed bars in which the bend angles were more nearly constant were much more uniform. In general, the resintered compacts yielded less variable data than the repressed material in which the degree of work hardening may have had some effect.

Table III—Experimental Variations in Properties of Iron Compacts Processed Identically

	Repressed		Resintered	
	Average	Max. Deviation	Average	Max. Deviation
Porosity, %	12.4	+0.7 −2.1	12.4	+0.2 −0.6
Tensile Strength, Psi.	46,120	+1680 −2020	33,230	+770 −580
Yield Strength, Psi.	—	—	23,375	±375
Bend Strength, Psi.	67,090	+2560 −4740	67,840	+12,810 −10,990
Bend Angle, Deg.	8.75	+1.25 −1.75	25.4	+15.1 −5.2
Shear Strength, Psi.	40,140	+2053 −3290	33,010	+880 −717
Impact, Ft.-Lb.	2.8	+0.8 −0.6	8.3	+2.5 −2.1

Compacting Pressure — 120,000 psi.
Sintering Temperature — 1100 C (2010 F)

Inter-Relation of Quality Characteristics

Possibly the most widely accepted and specified criterion of materials is tensile strength, but only a few powdered metal compacts are of such a size and shape that tensile specimens can be machined from them. Compacts pressed in the shape of sub-size flat tensile bars have come into wide usage, but the physical properties of processed powder parts cannot be correctly evaluated from data obtained with compacts of different size and shape, particularly when the width/length/thickness ratio is different.

Tensile tests made on bars prepared especially for that purpose are considered desirable in the determination of the quality of the product of a given method of processing powdered metal materials and in establishing the utility of the method. Such bars should be compacted in a rectangular cross-section

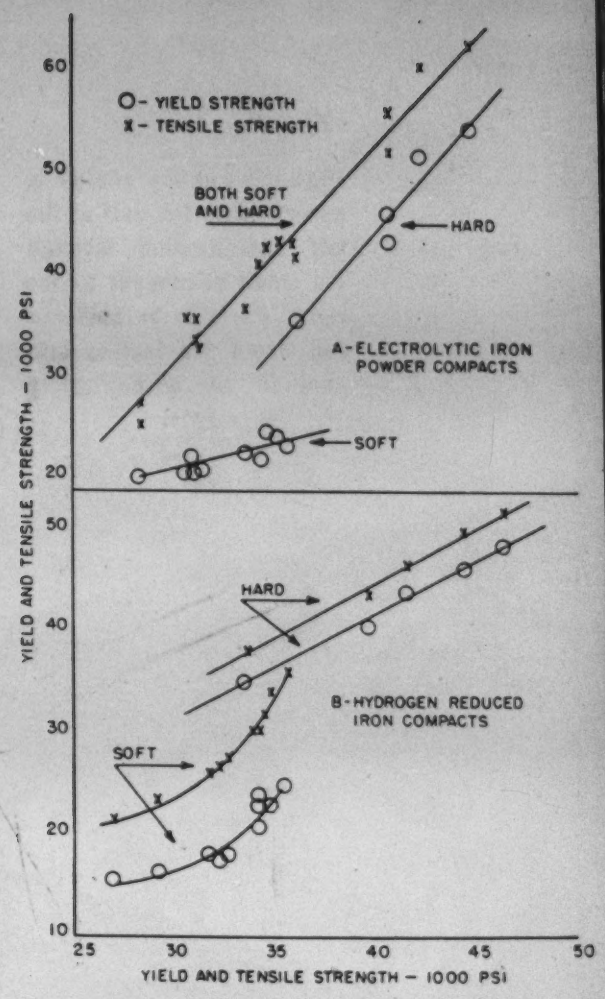
and submitted for test with the qualification samples of a given part. These bars could then be tested, not only in tension, but also in bend, shear and impact so that a standard for comparison can be established. Such a standard is necessary for the use of bend and shear data in appraising the tensile properties by means of curves relating different quality characteristics.

Both yield and tensile strength are proportional to the shear strength. For electrolytic powder compacts, the tensile strength of hard (repressed) and soft (sintered or resintered) material is related to the shear strength by a continuous curve whereas for hydrogen-reduced compacts separate curves are necessary to adequately present the relationship of the values of these properties for hard and soft material. This difference may be accounted for by the fact that specimens machined from compacts formed from electrolytic powder and the soft compacts made from hydrogen-reduced powder deformed sufficiently to reach a maximum load and to begin deforming locally (necking) before fracture, whereas the hard compacts of hydrogen-reduced iron broke before necking commenced. Thus, in the case of the less ductile compacts, the maximum load is a measure of the stress required for fracture and not the stress required for a local necking to begin. A correlation between tensile and shear strengths can be expected only when the specimens deform sufficiently for the load to reach a maximum and fall off, which was not the case for the hard compacts made from hydrogen-reduced powder.

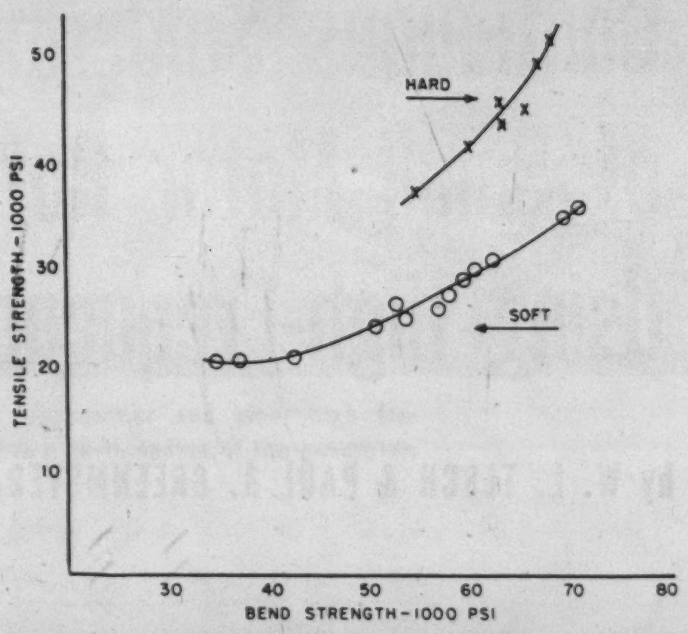
The ductility of powder compacts may be translated into more often used elongation values by correlating bend angle and elongation. The bend angle is defined as the number of degrees through which a ¼-in. dia. test bar is bent before the appearance of a crack on the under side. The measurement is sensitive only to plus or minus 5 deg. since it is affected by mechanical variables such as the number of degrees through which the bar is bent due to the relaxation of load upon fracture and the travel of the head before the cracking is apparent. The correlation between bend angle and elongation is not useful in the measurement of elongations of less than 2% or with a greater accuracy of more than plus or minus 2%, but it may be a very practical method for controlling the ductility of powder compacts. Separate curves must be drawn for purposes of relating the elongation and bend qualities of compacts formed from different grades of powder.

The bend test may also be considered as an indicator of the tensile strength of powder compacts. The correlation between ultimate bend strength and tensile strength is not as close for low strength material as for the stronger compacts and, therefore, the portion of the curve which applies to the properties of finished parts should be ascertained before applying a test similar to this in the determination of tensile strength.

Correlations of quality characteristics may be very useful in quality control of powdered metal parts, but it is essential that the closeness of the correlation be determined, the percentage of experimental error allowed for, and due allowance made for deviations of some compacts from the standard mean. The curves presented in this article are not the only ones which may or should be used. They are presented as an indication of the relationships which may be expected in normal structural parts.



Relationship between yield and tensile strengths in iron powder compacts.



Relationship between tensile strength and bend strength of hydrogen-reduced iron compacts.

Acknowledgement

The author wishes to express his appreciation to the Ordnance Department for permission to publish the result of this investigation, which was carried out at the Watertown Arsenal Laboratory as part of their basic research program.

High-frequency energy is generated in the unit at the left and applied through the small equipment at the right. Parts to be soldered roll down the incline into position at a controlled rate.

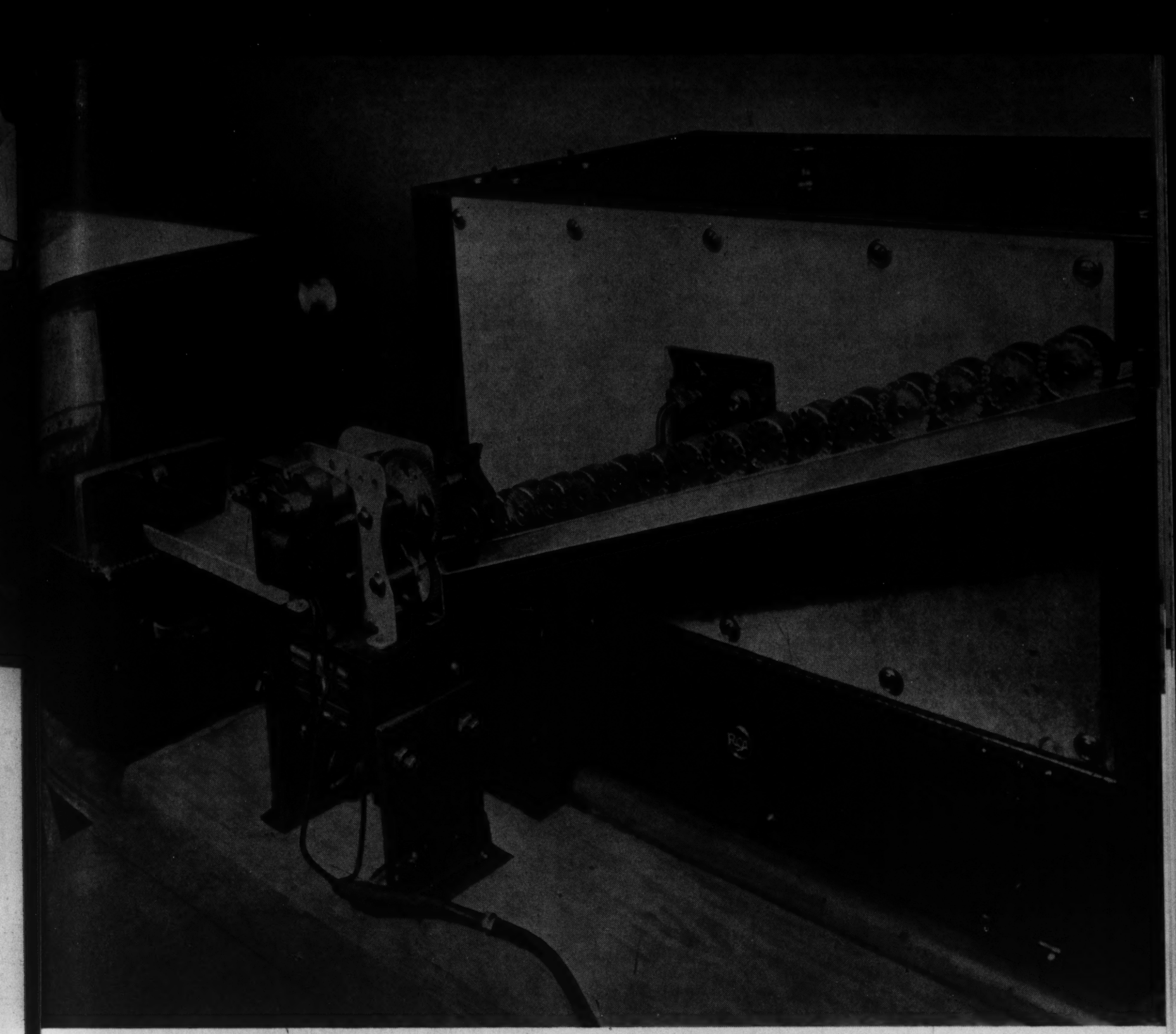
Continuous Soldering of Small Motor Rotors Using High-Frequency Heat

by W. L. TESCH & PAUL A. GREENMEYER, *Engineering Products Dept., RCA-Victor, Camden, N. J.*

High production and accurate control are achieved in the soldering of tiny motor rotors through the use of high-frequency heat and automatic feeding.

A PRACTICAL APPLICATION of high-frequency heating to the soldering of conductors to end rings in small squirrel-cage motor rotors has been successfully made by the Samsel Time Control Co., Spring Valley, Ill. The rotors are ¾ in. in length and 1 in. in dia. The process is continuous with a production rate at the present writing of 600 per hr., which compares favorably with the old rate of 150 per hr. The high-frequency power equipment consists of an RCA Type 2-BL, 2-kw. Electronic Power Generator, with Applicator.

Previously, the soldering process was that usually employed for making small squirrel-cage motor rotors. Briefly, it consists of assembling the silicon-steel laminations, copper conductors, and copper end rings in a jig that insures accurate centering. The stacks are then twisted slightly for necessary "skew"



This applicator unit houses the output current transformer and other high frequency components. It can be used anywhere within a 25-ft. radius of the generator.

and the ends of the conductors are peened over or staked so that a rigid assembly results. Joint areas are fluxed and then soldered by dipping each end of the rotor into molten solder.

This hot-dip method is cumbersome, requiring the use of tongs, and is rather wasteful because too much solder adheres. The job is somewhat messy; the joints are not so clean as could be desired. The process is slow because two dips are required, one for each end, and time must be allowed on each dip for the rotor end to come up to soldering temperature (about 480 F).

When high-frequency heat is used, the ends of the conductors and the end rings are tinned prior to assembly. (Although a hot dip is used, these small parts are easily handled, do not remain in the pot long, and solder is shaken off easily to give a clean, tinned surface.) Assembly, using a fixture, and staking operations remain unchanged. But for soldering, the assembled rotors are rolled down an inclined track and through an electromagnetic field established by a work coil. The currents induced in the ends of the rotors generate heat which melts the solder and "sweats" the conductors to the end rings. Sufficient solder is present as a result of the pretinning operation to produce a clean and entirely satisfactory joint.

Details of Construction

The inclined track is constructed of Transite, is 2 in. wide by ¼ in. thick, and is inclined at an angle of 15 deg. A recessed center channel in the track, ¾ in. wide and ⅛ in. deep, insures accurate positioning of the rotors with respect to the work coil.

The rate of feed is controlled by a motor-driven index wheel. This wheel or cam is shaped so that it permits smooth and uniform movement of the rotors, with resulting joints of consistent quality. When the rotor is released by the index wheel, the rotor plunges into a water bath for cooling. At the present time, an operator places the rotors on the track; however, a hopper has been designed and is in the process of construction so that eventually operation will be fully automatic.

The work coil is designed to generate the correct amount of predetermined heat and in the desired area. As is well known, high-frequency heat lends itself to exactness of control impossible with other heating methods. The work coil consists of a single turn of 3/16-in. copper tubing which is connected to the current transformer secondary. Water flows through the coil for cooling purposes; cooling is needed because of the concentration of power and for general efficiency of operation. Work coil voltages are low and offer no safety hazard if accidentally touched by operating personnel. The rotors and the work coil do not at any point touch each other; the rotor merely travels through the magnetic field established by the coil. Overall length of the coil is approximately 6 in.

For convenience, the high-frequency equipment is divided into two units. The main unit, the high-frequency generator, houses the high-voltage rectifier, the main control and protective devices, and most of the high-frequency components. The applicator unit houses the output current transformer and its associated high-frequency components. It is connected to the generator by 25-ft. cables and can be located on top of the generator or in any desired work position within a 25-ft. radius of the generator. In this way the generator can be located in some out of the way spot, where it does not take up room in the work area.

Both the applicator and the generator have on-off buttons and power indicator lights so that either can be used for control. A foot switch is also provided for applying the power by that means when desired.

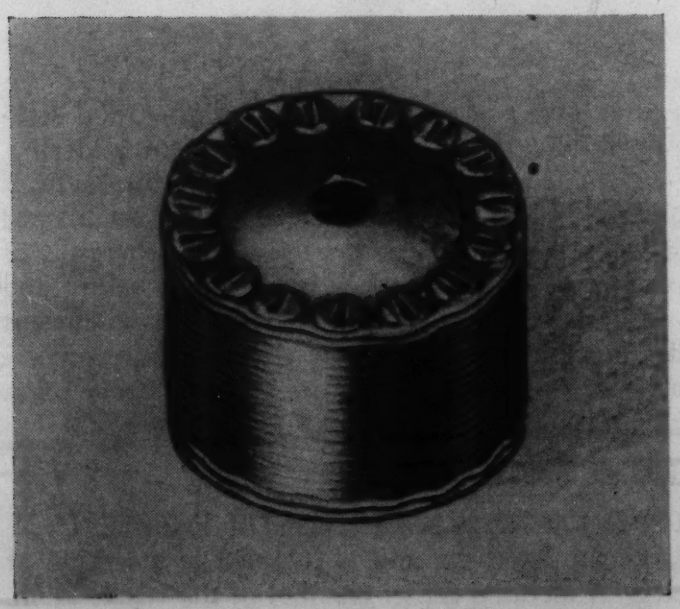


Fig. 3—This is one of the small motor rotors which are soldered automatically by means of induction heating.

Both the generator and the applicator are forced-air-cooled by separate internal blowers, while the work coil is water cooled. Stopcocks are provided at the rear of the applicator for water connections to a source of tap water at 0.5 gal. per min.

The generator converts the 60-cycle power supply to a frequency of approximately 400,000 cycles per sec., using two 833A tubes in parallel and employing a Colpitts circuit. The input is 205/240 v., single phase, at 85% power factor.

Results

Good soldering is obtained by using only the solder which adheres as a consequence of the pre-tinning of the rotor parts. Since induced currents heat the parts and the heated parts, in turn, melt the solder, "cold" solder joints cannot occur. The soldered joints are always clean, there is no mess, no waste. Results are uniform because human judgment does not enter into the soldering process. The output has jumped from 2½ to 10 per min., which is an increase of 300%. Costs have been lowered in almost direct proportion to the increase in production.

The same type of high-frequency heating set-up can be used for other soldering jobs involving objects to be soldered around one or both ends, or anywhere around the body of a round object. (For rectangular objects a conveyor belt set-up is usually employed for continuous operation.) External or internal joints can be either soldered or brazed. The inclined track technique can also be applied to hardening and other heat treating jobs. Index wheels can be designed to suit the workpiece, the rate of feed may be either fixed or variable, and the whole process can be made completely automatic. The work coil could be designed so that work pieces of different diameters may be processed without changing the set-up.

The high-frequency equipment has been designed for adaptability to the various requirements of both continuous and fixture type soldering and brazing operations, as well as small heat treating operations. Provision is made for varying output power in 10% steps over the entire range. In addition, vernier control provides for fine power adjustments between the 10% steps. Moreover, the secondary of the output transformer consists of a two-turn copper sheet with terminal arrangements for connecting these turns either in series or in parallel. Thus, the equipment provides the flexibility needed in matching various loads and is suitable for connection to many smaller and medium sized jobs on various types of materials.

High-frequency heating is not the answer to every soldering or brazing job, but when difficulty is encountered or results are not entirely satisfactory, it should be considered. It offers unexcelled heat control. Heat can be sharply localized or spread over a wide area, as well as controlled in depth of penetration. By its use heat spread damage can be radically reduced and predetermined quality results may be definitely assured. More and more high-frequency heating is proving satisfactory and economically feasible for soldering as well as for heat treating applications.

The manufacture of balls used in ball bearings and as the rotating tips of the latest style writing instruments is an intricate and interesting process.

These balls are so small they are weighed on a precision chemical balance. About 7,000 balls weigh 1 oz. and are valued at about $2,000 per lb.

Manufacture of Balls for Bearings and Pens

by JAMES PORTERFIELD

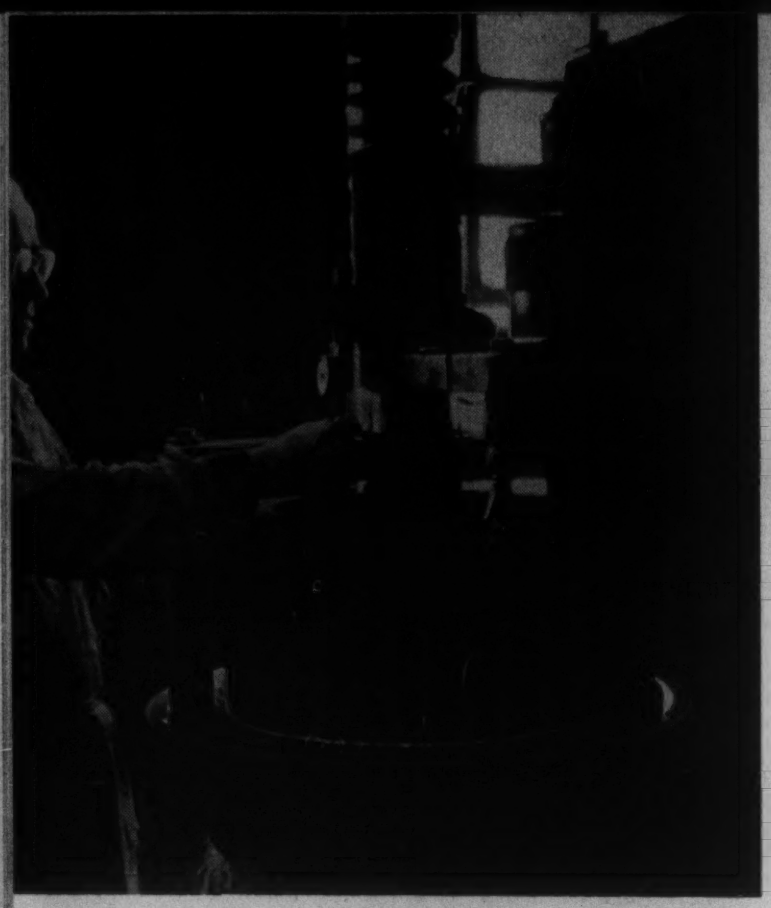
THE IMPORTANCE OF ball and roller bearings to the military machine is known to the layman from the frequent spectacular bombings of bearings plants in Germany—plants that were the most heavily defended of any target and where American and British aviator losses were most severe. Equally important to the Allied cause were their own bearing manufacturing plants in Britain and the United States.

American plants reached their acme of performance in the manufacture of bearings for the bombsights, where tolerances were measured in millionths of an inch. So precise in movement were some of the bearings that they revolved freely when touched with the tip of a camel's hair brush. Others were so small they could be oiled only with hypodermic needles.

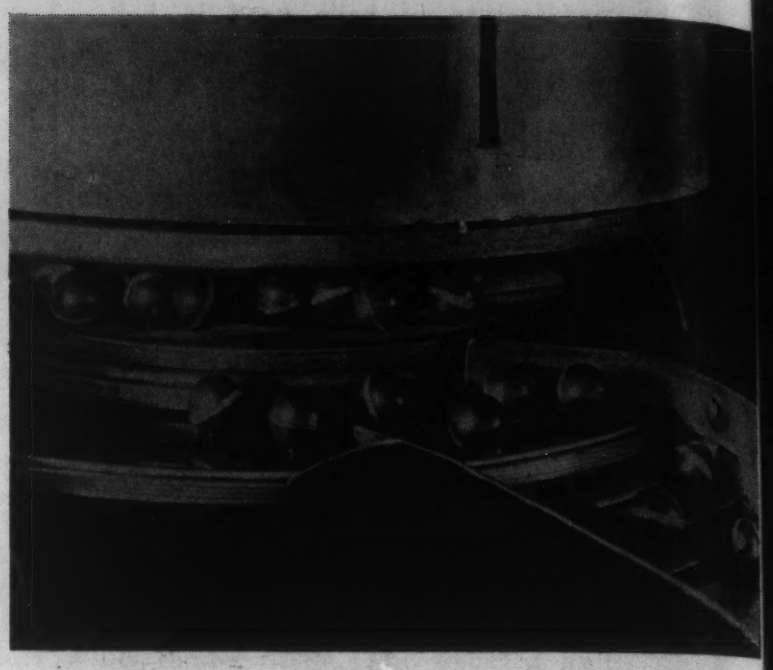
The war called for bearings that were smaller, more compact, more accurate and of higher quality than ever before made. Not only the bombsight but the automatic pilot, radar equipment, torpedo and bomb control mechanisms, electrically-operated gun turrets and many other precision devices, all delicate in construction and demanding exactness and freedom of movement, were dependent on exceptionally accurate and delicate anti-friction bearings.

The most critical bearings were not manufactured in ordinary plants since so many special conditions had to be set up involving constant temperature, humidity and cleanliness of air. Many of the most exacting bearings were made in a windowless SKF plant at Lansdale, Pa., atmosphere and lighting being entirely artificial. As the process proceeded to the finishing and final inspection, room temperature was kept to a narrow range around 76 F and humidity was always low at 40% and constant.

Women workers wore lint-free garments, including gloves to prevent deadly perspiration from corroding delicate balls. Signs throughout the finishing rooms forbade the eating of fruit since a drop of juice from a lunch box orange might ruin a batch of balls worth several hundred dollars—a prohibition adopted from the watch makers. Window drapes in the gaging and inspection room are not mere ornaments. Thus, because irregular glare reflecting from balls prevents



Wheels, running counter clockwise, apply a soft grind to 2½-in. balls. Grinding is the first step after balls have been formed from heated steel slugs.



On the flasher, balls roll from the center to the rim. The balls, through centrifugal force, roll between the plates where flash and nibs on the poles are shaved off.

proper detection of defects under visual inspection, harsh daylight streaming through windows must be adequately screened. Fluorescent lights, rather than tungsten, also permit more efficient inspection, as well as being easier on the eyes.

Techniques used in the war are already being applied to peace. Thus, a minute ball now being made for new type "permanently filled" fountain pens has a diameter of only 0.03937 in., about half the size of a pin head. Its allowable diameter variation is 50 millionths in., or less, while sphericity must be correct within 10 millionths.

The steel used in manufacture of small balls (1 mm. to 7/16 in.) is 52100, with following analysis: 0.95 to 1.10 carbon, 0.25 to 0.45 manganese, 0.025 phosphorous, max., 0.025 sulfur, max., 0.20 to 0.35 silicon, 0.40 to 0.60 chromium, 0.35 nickel, max., 0.25 copper, max., 0.08% molybdenum, max. All SKF steel is made in the electric furnace.

Ten Basic Steps in Manufacture

It is well to consider some of the basic steps in ball manufacture and to answer the question: How are balls made round? The steel arrives in the plant in two forms: First, wire for cold pressing balls up to and including 1 in. in dia.; second, bars for hot pressing balls more than 1 in. in dia. There are usually ten steps from raw material to glistening ball: Pressing, flashing, rough grinding, multiple groove grinding, tumbling, heat treating, precision grinding, lapping, inspection and gaging.

The pressing machines snip off short lengths of wire, or slugs, and press them between cup-like depressions in the dies at the rate of 400 per min., making a product that is "almost a ball." A slightly raised belt of excess material is seen around the equator, or flash. So much for the cold pressed dies up to 1 in. dia. For the larger sizes the balls must be hot pressed.

In the hot press department a big shear slices off pieces of steel bars 2 in. thick, which are placed in the furnace, then grasped by tongs and placed in the cupped dies of the press. The operator steps on a pedal and the rough ball is quickly formed. About 500 lb. of ¾-in. balls are fed from a hopper into an area between two file cut disks, the upper stationary and the lower rotating. The balls, impelled by centrifugal force, roll between the plates, whereupon the flash and nibs on the poles are shaved off. It is a 2-hr. job for the 500 lb.

At the time the balls are ready for rough grinding the ¾-in. balls are 0.035 in. oversize. In the grinding machine the pellets are rolled in a slot between a lower grinding wheel rotating clockwise at 900 r.p.m. and an upper driving ring going counter-clockwise at 60 r.p.m., with hourly production of 1,068. Including this and subsequent operations the balls are continually changing their axis of rotation, each spot on the surface thus receiving identical treatment. Rough grinding leaves the balls varying from one another in size and sphericity only 0.002 in.

The next steps, multiple groove grinding, by the Hoffman method, brings them to a uniformity within 0.0001 in. A batch of the ¾-in. balls in this department consists of about 4,000. The coolant is an extremely thin light oil that keeps the wheels sharp, clean and cool and the work clean; also allows small balls to be flushed into and out of the machines. In another room 1,000 lb. of balls are placed inside tumblers, 5 ft. in dia., rotating at 30 r.p.m. Here the balls, rolling in abrasive grit and water, are brought down to size for heat-treating. Using a compound of Vienna lime or white rouge, tumbling removes 0.0001 in. from the balls. Sawdust and chamois are used in barrels to clean and burnish the balls after tumbling.

Multiple groove grinding is performed in a special machine which brings balls down to within 0.0001 in. of size.

Lapping, also done in special machines, finishes balls to even greater accuracy—about 25 millionths of an inch.

Heat treating consists of hardening, quenching and tempering, with 1500 F reached in the first process. In hardening, a controlled atmosphere is used for some races, butane gas being cracked to eliminate oxygen, carbon dioxide and water. Balls are quenched in water; the races, in oil. Precision grinding follows, the balls being forced against a grinding wheel 2 ft. in dia., rotating at 60 r.p.m., the balls following a path determined by guide plates. In 12 hr. they will be true to size and sphericity within 0.00005 in.

There are four grades of Atlas balls made by SKF. Grade 1 are for precision ball bearings, accurate valve applications and for purposes demanding balls of the finest possible quality. Only Grade 1 pass through the lapping operation which splits the previous tolerance in half or within 25 millionths of an in. The lapping machine resembles the flashers and contains a special lapping compound. Extremely smooth surfaces on a ball assure free rolling and in a bearing means a maximum amount of contact with the race, resulting in minimum noise and an equalized load distribution.

Special Techniques

So much for conventional methods of manufacture. Some special problems came when SKF began secret work on the development of bombsight bearings in 1929. The balls generally were 0.125 and 0.15625 in. in size and were supplied in large quantities with a maximum variation of ±ten millionths. SKF was able to produce batches of 350,000 of the 0.15625-in. balls or 750,000 of the 0.125-in. balls within the desired tolerance. It is, of course, difficult to measure individually small balls in large volume at a cost within reason. It is most practical to produce the desired uniformity in the manufacturing method.

Inspection consisted, therefore, of taking a few balls from each large batch after grinding and lapping, assuming, if correct, that the entire batch was satisfactory.

A special lapping process was developed by SKF engineers for finishing the bombsight balls, which is now being used in the manufacture of 0.03937-in. balls and other miniatures. The process imparts a lap surface rather than a high polished surface generally given to steel balls. The lap surface consists of thousands of minute scratches, giving the ball a satin finish. Such a surface allows for better cohesion between the lubricant and the ball surface. For the modern ball of the "permanent inked" fountain pen, it holds and feeds out the ink more smoothly.

Inspection Plays Major Role

The inspection department of SKF is of equal or greater importance than the production department. It at least has more modern and glamorous equipment and background. A high type of woman worker was found more accurate than her brothers. Not only are temperature and other conditions well nigh perfect, but there are 15-min. periods of music and rest periods to ease the tension.

Perhaps few realize that it was SKF who ordered developed the Profilometer in 1937. In bearings extremely smooth surfaces, along with accurate dimensions, assure minimum noise and an equalized load distribution. Operated by electricity, it is possible to measure the peaks and valleys on steel surfaces with readings in micro inches, "root mean square." At the time of the development of the Profilometer, SKF was trying to produce the smoothest running bearings possible and there was believed to be a correlation between bearing vibration and surface roughness. At that time there was no proof of this and no means to measure surface roughness. Research led to the development of the Profilometer.

Balls for anti-friction bearings obtain their final polish in revolving rubber-lined tumbling barrels. Here a worker cleans the balls with air after tumbling.

Completed bearings get a final test on another SKF development of 1940, a noise testing machine operating on an electrical magnification principle. The bearing is rotated on a spindle with an electrical pick-up resting on the outside diameter of the bearing. Any vibration is magnified through an electrical circuit and transferred to an indicator where a reading is given in decibels. It is so sensitive that a microscopic scratch or minute speck of dust can be detected.

Measuring of fine ball tolerances is accomplished with electro-limit gages and electronic gages, used in connection with constant temperature and constant flow of oil. Size is controlled throughout the ball-making plant through the use of comparators and Johansson gage blocks. The Zeiss optimeter, which measures to an accuracy of 0.000025 in., and the Micropater, made by the C. E. Johansson Co., Sweden, also are used. The latter is accurate for measuring balls within 0.00005 in. The fastest method of gaging balls with allowed tolerances of 0.00005 in. is with an automatic gaging machine developed by SKF. Balls are poured into a hopper which in turn automatically feeds them onto two carefully set lapped steel blades. As the balls roll down the slightly inclined blade edges, they drop into compartments according to size.

In view of the modernity of the ball point fountain pen it is well to comment further. The satin-like finish imparted balls in such pens is found superior where a uniform flow of ink is desired and in instrument applications where the balls come in contact with one another without being separated by a retainer or cage. There are thousands of minute scratches, invisible to the naked eye, on the 1-mm. balls, such as used in the new pens. As the size of ball is increased, the number of scratches is increased. In other applications, such as jewel points in watt-hour meters, the smooth finish is better.

The hardness generally required on balls is Rockwell 65 C, while that of small races is 63 to 65 Rockwell C. SKF developed automatic furnaces for the heat treating process. Temperatures are automatically controlled by standard instruments, with two couples and two controls for each furnace, one set in the pre-heating zone, the other in the soaking zone.

Several peace time uses for such balls are being experimented with. Thus, watch makers may use minute and precise balls in the place of jewels, experiments being in active progress.

These girls are "listening" for dirt. Finished bearings are tested on equipment which amplifies any sound caused by dirt, scratches or other imperfections.

MATERIALS & METHODS MANUAL

27

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Hard-Facing Materials

by H. R. CLAUSER,

Associate Editor, MATERIALS & METHODS,

Assuming that hard-facing has been decided upon as a method of preparing a part for extremely rugged service, or for building-up worn surfaces of parts already in use. Now comes the big problem—which one of the many types of hard-facing materials will be most satisfactory? Here are discussed the basic types of hard-facing materials and the reasoning processes to be applied in their selection. Also included in this manual is the most complete table of hard-facing electrodes ever published—a highly valuable reference list of electrode types, trade names, compositions and characteristics.

Contents

Introduction . . . . . Page 104
Materials—Types and Characteristics . . . Page 105
Selecting the Hard-Facing Material . . . . Page 109
Design Considerations . . . . . Page 111
Processing Considerations . . . . . Page 113

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Introduction

Perhaps the best way to describe this manual and its scope is to define first what is meant by hard surfacing and hard facing. The terms hard surfacing and hard facing may or may not be used synonymously, and their exact meaning generally depends upon who is doing the defining. Hard surfacing, and sometimes hard facing, is often used very broadly to mean any method of hardening a surface. This can include such things as case hardening, flame hardening, cold working, plating (particularly hard chromium plating), metal spraying, hot dip coatings and overlays with welding rods. For our purpose here, hard surfacing and hard facing will be used interchangeably and in a narrower sense. They will refer to only that hard surfacing done by welding.

Hard surfacing or facing by welding is accomplished by applying a welding rod deposit to a metal surface to provide a final surface that is harder than the original one. Where extra heavy overlays are required and weld deposits will not suffice, solid hard facing inserts are sometimes welded on the surface to provide a new, harder face.

This manual will not go into the details of hard-facing procedures, nor describe the wide range of uses and advantages of hard facing. It assumes that hard facing has already been decided upon. The main purpose of the manual is to serve as a guide to the selection of proper hard-facing materials to meet requirements of particular hard-facing jobs. Obviously, it cannot give all the information needed to make final selections for specific jobs. But it can help by giving a broad view of the many hard-facing materials that are available and pointing out their principal characteristics and properties. After that, on-the-job advice on specific problems must be sought from the manufacturers of hard-facing alloys.

Selecting the proper hard surfacing material is a very important step in the hard surfacing process, because the life of the hard facing is largely dependent upon this materials selection. The problem of which alloy to use is usually rather complex because, generally, there are a number of interdependent factors involved, and no one hard-facing material is most satisfactory and economical for all applications.

The large number of welding rod manufacturers, each with their own line of hard-surfacing rods designated by various trade names, does not help to simplify this task of selection. Although most of them gladly supply information on their products, it is still hard to get an objective picture of just what is available and to decide from the mass of promotion literature which alloy will do the best job.

Hard facings can be applied to parts for wear resistance, corrosion resistance, heat resistance, or any combination of these three; but most hard surfacing is done to prevent wear, and this application of hard facing will be stressed.

Since the object of most hard facing is to increase wear resistance of metal parts, a few words on the subject of wear and how wear resistance is evaluated are in order. The result of wear is loss of metal and this loss can be caused and accelerated by a number of different forces. These include abrasion, impact, erosion, corrosion, galling and high temperature. The most important single factor effecting wear is abrasion, and the majority of hard-facing applications are concerned with the problem of minimizing it. However, the other factors mentioned cannot be ignored since they are often present to influence the kind and speed of abrasive wear.

Measuring or evaluating wear is not an easy matter and there is no one test or group of tests that will completely evaluate wear resistance characteristics of hard-facing materials. There is no such thing as a wear factor which is applicable under all service conditions. Wear, like corrosion, is a result and can only be determined precisely for one particular set of circumstances at a time.

Most evaluations of wear resistance at present are based on past experience and actual tests of materials in service. Such service tests, although valuable for a specific case, can be misleading if results are interpreted in a general way for other applications. Thus, actual service tests must generally be considered only qualitatively and for one given set of conditions. But in spite of the obvious limitations of field tests and of observation of hard-facing materials in service, it is the accumulation of knowledge secured in this manner that must be heavily relied upon when searching for the best alloy to use in a particular hard-facing application.

There are, however, some mechanical properties which are pertinent to the hard-facing selection problem. Hardness and toughness generally are considered the two most important. Hardness values of facing materials, however, must be used with caution. Abrasive wear is usually a result of scratching action; and since a material can only be scratched by a substance harder than itself, it would appear that the harder the facing the higher its resistance to abrasion. But it will be shown later that the hardness values ordinarily obtained by regular Rockwell or Brinell methods are not a true indication of their wear resistance and that micro-hardness testing must be resorted to.

Toughness is closely associated with hardness, because they usually counterbalance one another—as hardness increases, toughness decreases and vice versa. Since a great many hard-facing applications involve impact stresses to some degree, toughness must generally be weighed along with the hardness.

Materials—Types and Characteristics

There are virtually hundreds of different hard-facing alloys on the market today. Fortunately, practically all hard-

facing materials can be sifted down into a few major classifications; and the alloys falling in each of these classifications have many of the same general properties and characteristics.

Hard-facing materials are manufactured in three principal forms: as welding rods, as insert shapes, and in powdered form. Welding rods whose composition is similar to that of commercial wrought alloys, are produced from drawn wire. If the rod is for electric welding, a flux coating is usually added. As the alloy and carbon content increases, drawing becomes increasingly difficult, so high alloy and high carbon rods are cast. These are also flux coated when used in arc welding.

Also available are composite rods that consist of a thin shell or tube in which are enclosed various hard-facing ingredients. And still another type have the hard-facing ingredients carried in the flux coatings. In such cases the rod itself is usually of low carbon steel and the flux serves as the alloy carrier in addition to doing its other jobs as arc stabilizer and slag former.

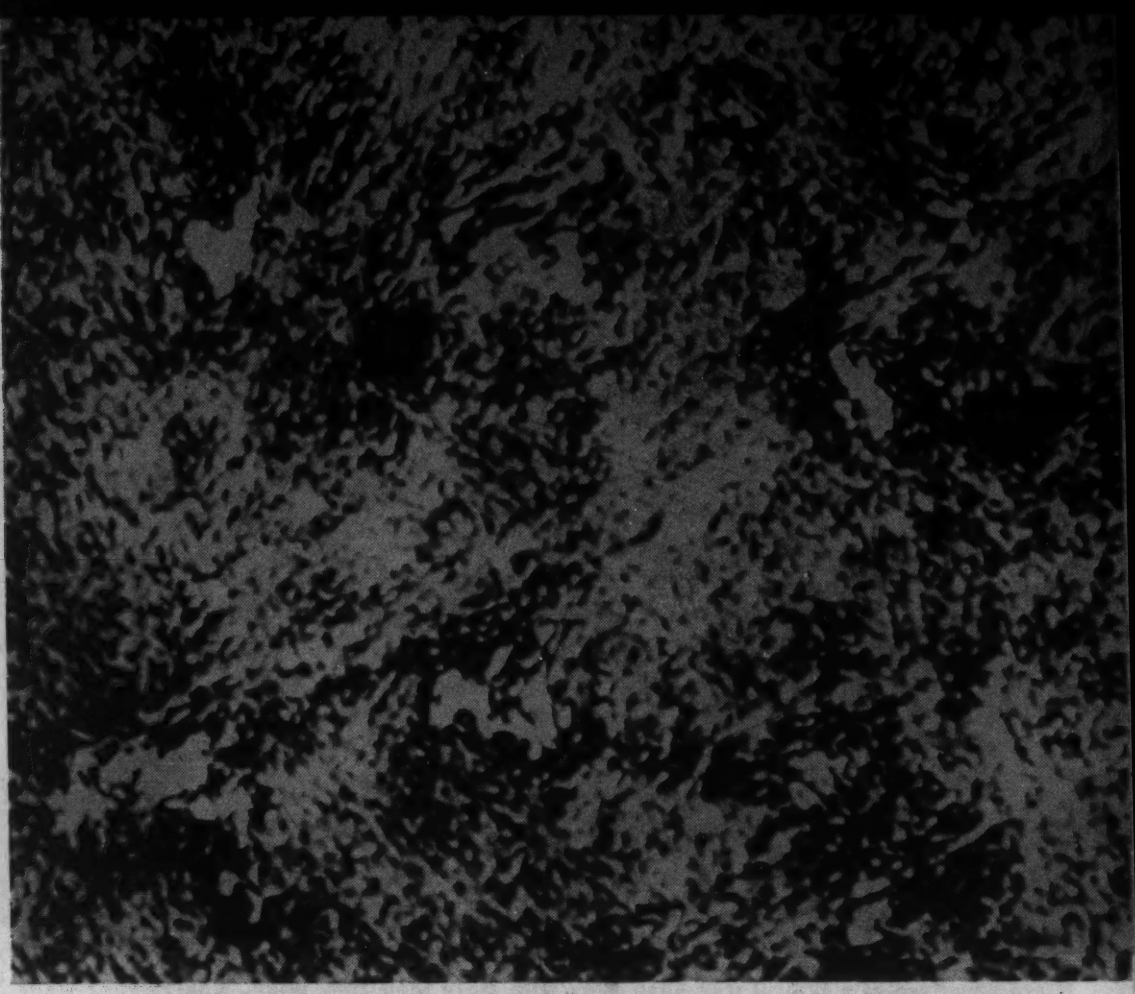
Where extra heavy hard-facing is required, inserts and filler bars can be used. These are cast and are available in a variety of shapes. The filler bars are often supplied rather long and then can be cut to the length desired. Inserts and filler rods are embedded on the surface to be faced by welding or "puddling" them in place.

Hard-facing powders are produced in plain powder form or are mixed in a paste. In either case the material is spread over the base metal; the base metal is heated to the melting point to firmly embed the powder particles into the surface.

Structure of Hard-Facing Alloys

As was pointed out previously, service performance of hard-facing alloys cannot be compared on a regular Rockwell or Brinell hardness basis. It is also true that comparing alloys on the basis of chemical composition is often unreliable since it is possible to produce a required structure in different alloys or different structures in the same alloy by heat treatment. Thus, the final structure is not solely dependent on chemical composition.

It is the structure of metals that primarily determines their properties. So a study of the constituents in hard-facing deposits provides a means of explaining their wearing characteristics and comparing various hard-facing materials. All hard-facing deposits are heterogeneous in nature; that is, they consist of uniformly distributed particles of carbides held in a softer matrix. However, in some alloys the particles are so small that for practical purposes they are generally considered homogeneous.



Micro-structure of a typical iron-base alloy with less than 20% alloy. Analysis: 7 chromium, 3½ manganese, 1½% carbon and small amounts of silicon, molybdenum and zirconium. White areas are wear resisting carbides. 1000X (Courtesy: Stoody Co.)

Chromium in carbide form is perhaps the most important single wear-resistant ingredient and is a common alloying element in a majority of hard-facing materials. It has relatively good weldability and will alloy in all proportions, still retaining most of its carbide properties.

Carbon is another essential ingredient. Its primary purpose is to convert the alloying elements, particularly chromium, into hard carbides. At the same time it imparts its good impact properties, and weldability to materials.

Tungsten forms a carbide that is even more abrasion resistant than chromium carbides. It is extremely brittle and has no impact value. It cannot be used in the so-called homogeneous rods because of its high solubility in molten metal baths. It is used in the form of either cast inserts or small particles in composite rods. There are several other less common hard-facing ingredients that are similar to tungsten carbides. These include carbides of molybdenum, boron, columbium and tantalum.

It is the hardness of the carbide particles mentioned above and their distribution and size in the micro-structure that gives hard-facing materials their greatly increased wear resistance. The matrix in which the hard particles are held determines other performance characteristics of the alloy, such as corrosion, heat, and impact resistance. The hardness of the matrix may also have some influence on the alloy's wear resistance, but to a much lesser degree than carbides.

In order to understand the influence of hardness and structure on wear resistance it is important to distinguish between two kinds of hardness: (1) overall or "general" hardness of an alloy as determined by Rockwell or Brinell hardness tests, and (2) micro-hardness of the structural constituents of an alloy. Rockwell hardness values of all hard-facing materials, with the exception of one group, are generally no higher than heat-treated plain high carbon steel, and yet they will outwear high carbon steels from 2 to 20 times. Thus, it is evident that general Rockwell hardness is not very indicative of wear resistance. However, if micro-hardness readings are taken of constituents making up hard-facing alloys, the correlation between hardness and wear resistance is much closer.

Micro-hardnesses of alloy constituents are obtained using an instrument that consists of a very small diamond point which is impressed upon a

Micro-structure of a typical iron-base alloy with more than 20% alloy. Analysis: 33 chromium, 7 manganese, 4% carbon and small amounts of zirconium and silicon. White areas are the chromium carbides which take the brunt of the wear load. 500X (Courtesy: Stoody Co.)

polished surface under a spring load. The diagonals of the impression are measured under a microscope, and by use of a formula are converted to a hardness number. There are two different shaped diamonds that may be used. With one, the hardnesses obtained are known as Vickers Pyramid Numbers (VPN), and with the other they are reported as Knoop Numbers. Readings with micro-hardness testers are often converted to the more widely known Rockwell or Brinell hardness scales by conversion tables.

Table I gives the micro-hardness values of a number of constituents occurring in hard-facing deposits.

Classification of Hard-Facing Alloys

Methods or systems of classification of hard-facing materials differ rather widely; all are more or less arbitrary. The systems of classification most used are those based on metallurgical structure of hard-facing deposits and those based on chemical composition of the welding rod. At the present time the American Welding Society is working up a comprehensive classification system based on composition to cover all hard-facing materials.

Although classification by chemical composition is not always strictly accurate, it offers the most convenient system of organizing the large and diverse assortment of hard-facing alloys into easily recognizable groups; for this reason it is the customary method of classification. Actually, the difference between the structural and composition classifications is not too great: the groupings of alloys by structure ties in rather closely with those by chemical composition.

In this manual we will group hard-facing materials by chemical composition, and at the same time include an analysis of the general metallurgical structure under each group. For our purposes, then, hard-facing materials will be broken down into three broad groups as follows:

Group I — Iron-base alloys.
IA — Iron base, less than 20% alloy.
IB — Iron base, more than 20% alloy.
Group II — Nonferrous alloys.
Group III — Diamond substitutes (intermetallic compounds).

Group I—Iron-Base Materials

This group covers a wide variety of iron-base materials, the majority of which are specifically formulated for hard surfacing applications. However, there are some general purpose iron-base alloys which are sometimes considered as hard facings. These include stainless steels, tool steels, and certain cast irons. Although they will not be discussed here in detail, their possible use in certain hard-facing applications should not be overlooked.

The alloys in Group IA, containing less than 20% alloying elements, are lowest in cost and are primarily for arc application on large parts and heavy equipment and as a base for other, more expensive hard-facing alloys. Their principal characteristics are low cost and relatively high hardness (around 50 Rockwell C) and satisfactory toughness to withstand moderate to high impact. The chief alloying elements are chromium, manganese, and silicon. The carbon content may vary from low up to several percent. In some alloys there are also small ad-

Micro-structure of a typical nonferrous hard-facing alloy. Analysis: 25 chromium, 13 tungsten, 2% carbon, balance cobalt. The gray constituents are the carbides embedded in a cobalt matrix. 500X (Courtesy: Stoody Co.)

ditions of boron, tungsten, molybdenum, nickel and zirconium.

Hadfield manganese steel (10 to 14% manganese) is included in this group although not specifically designed for hard facing. Also included are white cast irons, containing sufficient alloying elements, such as chromium, nickel, molybdenum, and manganese, to provide hard carbides in a tough austenitic matrix. There are many special hard-facing jobs where these cast irons are suitable and give superior wear resistance. There are also some martensitic irons, notably Ni-Hard with nickel and chromium, which have very hard carbides in a hard martensitic matrix. In manufacture they require close technical control.

The simplest form in which Group IA rods are supplied is as a mild carbon steel rod covered with a flux coating that contains the hardening alloys. This form, however, is limited by the thickness of coating that can be applied to the rod. These hard-facing alloys can be cast, but in this form are relatively expensive and closely approach the price range of the other groups. Enclosing the ingredients in thin tubes provides a relatively low cost rod that has wide use.

Hard-facing materials in Group IB generally have alloy contents ranging from 20 to 55%. They are, of course, higher priced than alloys containing less than 20% alloy, but are usually harder and more resistant to straight abrasion. Their impact resistance is somewhat lower.

The alloy ingredients in these materials include chromium, tungsten, molybdenum, nickel, cobalt, boron, manganese, silicon, vanadium, and zirconium. Chromium is the chief alloying element and usually runs over 25%. Due to their high alloy content, the rods are cast.

Because of the high percentage of chromium, these alloys can be classed as stainless steels. The common stainless steels are not generally considered to be hard-facing materials in the strict sense. However, they are often considered for applications where corrosion is a primary factor and abrasion is secondary.

Hard-facing deposits from iron-base alloy rods can be either austenitic, pearlitic, martensitic or a combination of these in the as-deposited, air-cooled state. It is often difficult to obtain information as to what microstructure can be expected from a given rod. Wherever possible this information should be determined since the performance of the hard facing depends largely on its structure.

Martensitic deposits achieve full hardness in the as-deposited state and have a hardness range of 50 to 65 Rockwell C, depending upon the carbon content as well as the proportion of untransformed austenite. Their abrasion resistance is superior to austenitic and pearlitic steels, but their impact resistance is not as good. The higher the hardness of a martensitic deposit the greater is its resistance to abrasion, erosion, and galling, and the less is its resistance to impact. Examples of hard-facing steels with a martensitic structure (as deposited) are the "low" chromium steels having around 0.10 carbon, 2 to 9 chromium, and 0.5 to 1.5% molybdenum.

Austenitic weld deposits are often referred to as work-hardening, because they are relatively soft in the as-deposited state, but when subjected to cold work, hardness on the surface increases and ductility decreases. Below this hardened surface the deposit remains comparatively soft and provides good impact resistance.

Regular stainless steels are basically austenitic. High manganese steels are also a typical example of this structure. Thus, with austenitic deposits some form of impact in service is required before the hard-facing layer will achieve its full wear resistant characteristics. Because austenitic deposits provide a combination of high impact values with good abrasion resistance, their widest use is in applications where resistance to impact wear is required.

Pearlitic hard-facing deposits are the least common of the three. They are moderately hard (20 to 45 Rockwell C) and not particularly ductile.

The micro-hardness of the carbide constituents in iron-base alloys varies considerably. In the lower alloy group, where the carbide particles are very fine, the micro-hardness readings closely parallel the general Rockwell hardness of the alloy, because micro-hardness impressions are difficult to obtain directly on the constituents. Thus, the readings run from approximately 55 to 60 Rockwell C.

In the steels containing over 20% alloy, micro-hardness readings on the carbide constituents have values as high as 75 Rockwell C as compared to general hardness of 50 to 60 Rockwell C.

Group II—Nonferrous Alloys

This group covers nonferrous alloys whose main constituents are cobalt, chromium and tungsten. The compositions have chromium up to 35%, tungsten up to around 40%, and the balance cobalt. In some, molybdenum or columbium may also be present or may take the place of one of the chief ingredients. Small amounts of carbon and iron and deoxidizers such as silicon, manganese and boron may be included.

These alloys are available in several

Micro-structure of cast tungsten carbide particles embedded in a relatively soft steel matrix. 50X (Courtesy: Stoody Co.)

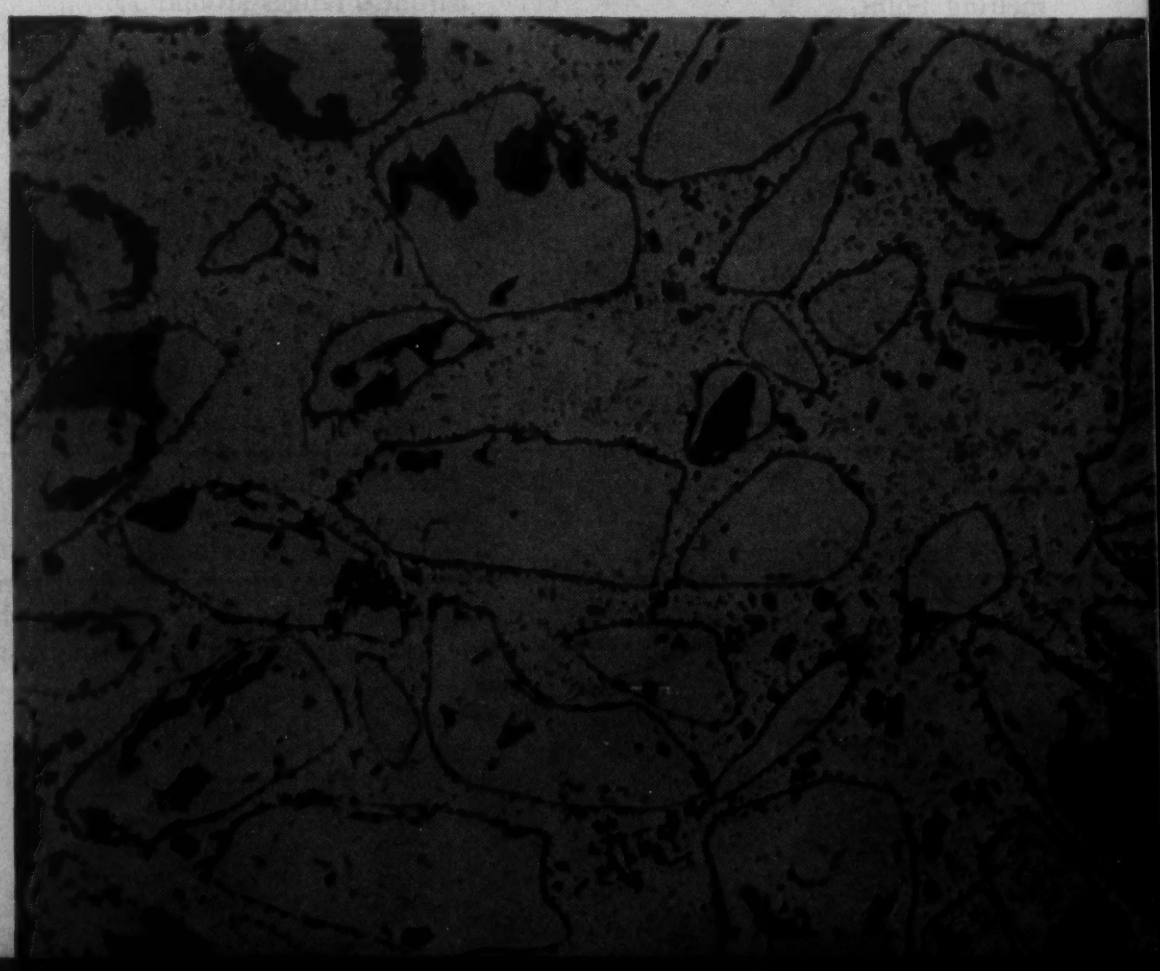


Table I—Micro Hardness of Constituents in Some Hard Facing Weld Deposits

Material	Constituent	Rockwell "C"	VPN (25 gm. load)
*0.20% C Steel	Ferrite	—	104
*1.6 Ni, 1.5% Cr white cast iron	Pearlite	—	314
*1.5 C, 11.8% Cr steel	Austenite Chromium carbide	— —	353 1960
*Ni-hard cast iron	Martensite	—	390-640
†4 C, 33 Cr, 7% Mn steel	Chromium carbide Matrix	75 52	— —
†25 Cr, 13 W, 2% C, bal. Co	Chromium carbide Tungsten carbide Cobalt matrix	71 79 46	— — —
†Cast tungsten carbide in steel matrix	Tungsten carbide Steel matrix	86 45	— —

*From Avery, "Hard Surfacing by Fusion Welding"
†From Sharp, "Micro-Structure of Hard-Facing Alloys"

grades to give hardnesses from about 40 to 55 Rockwell C. The harder of the series have the greatest resistance to wear, but the least resistance to impact and thermal shock. The softer grades have good strength and toughness; the softest of the group can be machined with carbide tools. These alloys are produced in solid rod form by casting in either permanent molds or sand molds.

Alloys of cobalt, chromium and tungsten have the quality known as "red hardness;" that is, they retain most of their room temperature hardness at elevated temperatures. This property results from the presence of cobalt which does not dissolve the other alloying elements, tungsten and chromium, until it is heated close to its melting point.

Also in this group are alloys having nickel as a base and either chromium and boron or chromium and iron as additional alloying constituents. They are comparable to the cobalt-chromium-tungsten alloys in their characteristics of high red hardness, and excellent corrosion resistance along with their high hardness. They have good resistance to galling.

The property of red hardness makes these nonferrous alloys valuable for high temperature wear resistant applications. They also have the ability to resist various corrosive media and oxidation at elevated temperatures.

The alloys in this group, because of relatively low melting points of the alloy combinations, have good flow properties. In addition, the thermal coefficient of expansion being close to the common base metals, good bonding with steel is achieved. Another important property is their ability to undergo heat treatment subsequent to welding without a change of hardness and wear resistance.

The structure of these nonferrous alloys consists essentially of chromium and tungsten carbides in a solid solution matrix of cobalt with small amounts of chromium and tungsten. The alloys owe their corrosion resistance as well as their "red hardness" to this cobalt matrix. Micro-hardness readings of these alloys show the chromium carbides to range up to 75 Rockwell C and cobalt matrices from 40 to 50 Rockwell C. General Rockwell C hardness ranges around 55.

Carbon, which may run from around 0.55 to 2.60%, is a very important constituent because it combines with the tungsten and chromium to form the wear-resistant carbides. Thus, the most abrasion-resistant structures are generally obtained in the high carbon range.

A few words should be mentioned here about bronze surfacing. This is really a soft surfacing operation and as such usually is not considered along with hard facing. However, one of the chief functions of bronze surfacing is to resist wear, and so in some applications bronze surfacing materials must be considered along with hard facing. Bronze surfacing finds use where there is relative motion between mating surfaces to reduce friction and wear. The surfaces of large forming dies requiring freedom from scratching and galling of surfaces is a typical application. Because of the relative softness of bronze facings (not over 40 Rockwell C), its application is usually limited to smooth mating surfaces.

There are several types of bronze surfacing alloys in common use. The chief ones for wear resistant applications are manganese bronze, phosphor bronze, and aluminum bronze. Of these, aluminum bronze is the hardest.

Group III—Diamond Substitutes (Intermetallic Compounds)

The materials in this group are referred to as diamond substitutes because their hardness approaches that of the diamond. The hardness ranges between 8.5 and 9.5 on the Moh scale where the diamond is given a hardness number of 10. The group includes the following intermetallic compounds: carbides of tungsten, tantalum, titanium and boron; and borides of chromium. Of these, tungsten carbide is the most widely used.

The tungsten carbides are available in three different forms: as rods, as powder, and as inserts. In the rod form tungsten carbide particles are either enclosed in a thin steel tube or uniformly distributed in a cast alloy rod. The rods can be coated for arc welding. Rods are available with a number of different grades or types of matrix; they are also supplied with various carbide particles sizes. Tungsten carbides in this form are applied in much the same way as ordinary welding rods. Because of the high melting point (4600 F), the tungsten carbide particles do not melt, but are bonded to the base metal in the matrix of a lower melting alloy. If the particles are very fine, however, they may dissolve and alloy with the matrix and give a smoother deposit with somewhat higher impact properties than ordinarily attained.

The most common powder form of tungsten carbides are those in which finely crushed carbide particles are sprinkled over the surface to be faced; the base metal is then heated to its melting point to bond the hard particles. In another form the carbide particles are mixed in a paste which is spread over the surface in the same manner as the other powder form.

Tungsten carbide inserts or shapes e formed by either casting or pow- metallurgy methods. They are pplied in a variety of sizes and apes. To apply them, they are set the surface or in grooves after the face metal has been "puddled" or welding them in place. Often the serts are later covered with a final at of another hard-facing alloy.

The materials in this group offer e maximum in wear resistance at rmal and elevated temperatures, but e low in impact value as compared the other groups. Carbide inserts ll crack readily under impact or thermal shock. The other forms of this group have better impact resistance but somewhat lower abrasion resistance than the inserts.

While in other hard-facing alloys the heterogeniety is microscopic, the composite nature of the structure in tungsten carbides is quite obvious. Thus, the metallurgical structure of the alloys in this group is similar to other hard-facing alloys in that it consists of hard carbide particles embedded in a softer, tougher matrix. As was mentioned previously, the size of the carbide composition can be controlled in the rod design. Vickers hardness readings taken on tungsten carbide particles and then converted to Rockwell C show values of 84 to 88. With such hard carbide particles it can be seen why Group III alloys are rated first in abrasion resistance.

The choice of matrix material to hold the hard carbide particles is more important than is often realized. If the matrix is too soft it may wear rapidly and allow the carbide particles to fall away. Also, corrosion, heat, and to a certain extent impact, resistance depend upon the matrix material. Alloys of the other two groups are often used as matrices.

Selecting the Hard-Facing Material

In any given hard-facing application ecting the best hard-facing alloy for e job can be fairly simple and ob- us or it may require a lengthy and ther complex analysis, depending on the particular conditions in- lved. If, for example, the part in- lved is subject to wear from only mple sliding abrasion, the choice will a great deal less complex than ere, in addition to sliding abrasion, er conditions such as impact, cor- ion, and elevated temperatures ght be encountered.

In most cases it will be found that select a hard-facing material for a rticular application, not one but ny such factors must be taken into sideration. Perhaps the most im- rtant are the *service conditions* to ich the part and a hard facing will subjected. These might include asion, impact and work hardening, ling, corrosion, erosion, heat and rmal shock.

Besides this variety of service con- ions, there are a number of factors e size and composition of the part be surfaced, finish and thickness deposit required, that must also be sidered. For want of a better phrase are calling such factors *design siderations*. Then, too, there are eral *processing considerations* such welding methods, heat treating, and chining or finishing subsequent to lding and possible rewelding over applied hard facing, that need to be en into account. And, finally, all- portant *cost* must be figured.

All these selection factors will be discussed separately, and wherever possible hard-facing materials best suited to meet each individual condition will be given. But again it must be emphasized that invariably not one but many variable conditions are encountered and the selection job in the final analysis is one of carefully weighing all the factors involved and finally choosing the material which is best for that one particular job at hand.

Service Conditions

As was mentioned earlier in this manual, the primary purpose of hard facing is to increase the wear life of a part by improving its abrasion resistance. So abrasion itself is the most important single service condition that must be considered when selecting a hard-facing alloy for parts that wear by coming in contact with other surfaces. The other service conditions that are encountered and which will be discussed either accelerate this abrasion process or are secondary factors incidental to abrasive wear.

Abrasion—

There are two main kinds of abrasion: (1) Sliding abrasion which is caused by one material sliding over another. This type of abrasion occurs in digging, crushing and grinding operations on parts such as shovel teeth and buckets, plow shares, and agitators of various kinds. (2) Rolling abrasion in which there is usually metal-to-metal contact by rolling or grinding action. Examples of this kind of abrasion are meshing gears and metal rolls.

There have been many attempts to work out some satisfactory method of quantitatively evaluating abrasion resistance of hard-facing materials, but all of them suffer from certain limitations that prevent their universal adoption. Their greatest limitation is that results obtained are only reliable for the specific conditions under which the materials were tested.

With one such abrasion test, which has been under development and used for about 18 years, the abrasion resistance of materials to very hard mineral particles (quartz) under moderate pressure and no impact can be determined. The results from this method may be used as a guide in selecting hard-facing alloys for applications having similar service conditions. It is a test involving sliding abrasion and is not indicative of metal-to-metal abrasion or rolling abrasive wear.

This wet sand abrasion test is described in detail in a monograph on hard surfacing prepared by the American Brake Shoe Co. Some of the abrasion factors obtained by them on a wide range of weld deposits are given in Table II. In this work a rolled plain carbon steel was taken as standard and assigned an abrasion factor of one. Materials with abrasion factors less than one have greater abrasion resistance than the standard. Thus, the lower the factor the greater the resistance to abrasion.

The test consists essentially of moving test specimens at the rate of 119

ft. per min. for 1.35 miles in contact with a standard abrasive (wet quartz sand). The loss in weight of the sample is determined. The abrasion factor is worked out in terms of weight loss in comparison with the standard.

It is generally true that most protection against abrasion is obtained with a material harder than the abrading agent. Thus, increasing amounts of carbides means increasing abrasion resistance. And alloys containing the tungsten carbides will have greater wear resistance than those with chromium carbides present. In iron-base materials, martensitic deposits surpass austenitic and pearlitic deposits in wear resistance.

For sliding abrasion, an alloy with a large quantity of very hard carbides in a tough, hard matrix seems most suitable, while for rolling abrasion the matrix need not be as hard and wear resistant.

In general then, for abrasion, Group III alloys rate highest; Group II and IB alloys rank second in order; and Group IA, last.

Galling —

This type of wear is not very often encountered in hard surfacing applications. It is a common and important consideration in bearing applications. Galling is different from abrasion in that the wear is caused by two similar metals "seizing," this resulting in a piece of the one surface being pulled out. High temperatures, by softening the metals and thus facilitating plastic flow, make materials more susceptible to galling. Metals that have the greatest tendency to gall are those with relatively low yield strength, such as low carbon irons and austenitic stainless steels.

Thin layers of hard-facing materials minimize this tendency to gall. Hard-facing materials which in application are very fluid and free flowing, and provide a thin, smooth high hardness deposit, are the best for this service. Additional advantageous properties are high compressive strength and "red" hardness.

The nonferrous alloys, Group II, are quite satisfactory for resistance to galling. Martensitic cast irons, having alloying agents such as chromium, nickel, molybdenum, tungsten, or cobalt to promote better high temperature hardness, are usually the most economical protection. A few sources advocate Group III materials as having good anti-galling characteristics.

Impact —

Most service to which hard facings are subjected involves some impact. Although impact forces do not cause wear, as we think of it in connection with abrasion, it is nevertheless tied in closely with the effective life of hard-facing materials. If an alloy is too brittle and cracks or shatters in service, the hard facing is useless no matter how wear resistant it may be. Since it is generally true that the alloys with the highest abrasion resistance have the lowest impact value, this factor of impact takes on added significance.

There are several different kinds of impact that can be encountered in service: edge impact that involves blows delivered to a sharp edge or edges, such as a chisel edge or scarifier teeth; flat impact where blows are struck perpendicular to a flat or nearly flat surface. In flat impact the shock is distributed over a wider area than in edge impact. However, where extra heavy compression or very heavy shock is applied to surfaces in any direction, such as impact on rails or dies, the effect is similar to edge impact.

For flat impact the hard-facing alloy need not be as tough as for edge and heavy compression impact; so where severe abrasion and flat impact are encountered, use one of the harder and high wear resistant alloys. However, in hard surfacing a part that must take severe edge impact, alloys in Group IA with less than 1½% carbon are most satisfactory.

Group IA alloys possess the greatest resistance to impact; Group IB alloys also have relatively high impact values, but not as high as Group IA. Nonferrous alloys (Group II) in the lower hardness range compare roughly with Group IA, and the harder nonferrous alloys are about the same as Group IB. The tungsten carbides, of course, have the lowest shock resistance of any of the hard-facing materials.

When considering iron-base alloys, it should be remembered that austenitic deposits give the best resistance to shock, while with martensitic deposits, shock resistance decreases with increasing hardness.

Work Hardening —

Closely connected with the factor of impact is the possibility of utilizing shock or cold working encountered in service to work harden the hard-facing alloy. This work hardening result when austenitic electrodes are used They produce a very tough and relatively soft deposit (20 to 35 Rockwell C). The surface when subjected to heavy blows hardens and exchanges ductility for hardness. This gives a case hardening effect that continues at the surface as metal is worn away at the same time the metal below the surface maintains its initial low hardness and excellent impact resistance.

Many of the austenitic welding rods of this kind fall into Group IA, and should be used wherever this work hardening characteristic can be used to advantage. However, in cases where severe abrasion can occur before the deposit has achieved its maximum abrasion resistance, they cannot be used

Elevated Temperature Service —

Hard-facing deposits must frequently withstand high temperatures. Sometimes the heat is created by friction as in high-speed cutting tools; in other cases the parts are subject to high operating temperatures, such as hot trimming dies, hot work punches and pins used in hot billet tongs. The heat, regardless of the source, produces a softening effect in many alloys and consequently materially lowers wear resistance. In addition, elevated temperatures may increase oxidation rate and corrosive action, if corrosive agents are present.

To avoid softening of the hard facing, alloys that are not readily annealed by high temperatures, should be used in elevated temperature service. For temperatures above 1000 F, nonferrous alloys (Group II) are suitable and widely used. In addition to tungsten carbides which are highly refractory, these alloys have a cobalt matrix which has high red hardness as well as high temperature corrosion and oxidation resistance. Perhaps not as common but equally suitable are the nickel base alloys which also are in Group II.

The tungsten carbides also retain their high hardness at elevated temperatures; however, often the matrix material cannot withstand elevated temperatures and will wear rapidly causing the harder carbides to be dislodged. To avoid this, a Group II alloy can be used as the matrix. For temperatures below 1000 F there are other possible alloys that are sometimes used depending upon service conditions involved. High-speed tool steel, for ex

ample, maintains a large part of its original hardness up to about 800 to 900 F. Certain alloys in Group IB possess a relatively high degree of red hardness, but this is not one of their chief characteristics. The Group IA alloys have no red hardness and above 600 F are subject to fairly rapid oxidation.

Thermal Stresses, Shock, and Expansion—

In addition to red hardness, the matter of thermal stresses that may be set up in a hard facing and part during the application and service is an important consideration. Thermal shock is caused by a very rapid change in temperature in a part. Tools such as hot-work punches and dies, and piercing punches, which are immersed in cold water frequently, are subject to high thermal shock. To avoid failures from fracture, the hard facing on such parts must withstand the high thermal stresses that are developed. Nonferrous hard-facing alloys of the cobalt-chromium-tungsten type have been found satisfactory for such service. Tungsten carbides in a high alloy matrix that will resist thermal shock have also proved suitable. Tungsten carbide inserts, however, will crack readily from thermal stresses caused by rapid localized heating.

Sharp temperature changes, caused by friction, also set up high thermal stresses that may result in heat checking. To avoid thermal cracking in such applications, the hard facing should have a modulus of elasticity as low as possible since the capacity to absorb thermal stresses is aided by plasticity.

In applying hard-facing alloys by fusion welding, stresses are usually developed from restrained expansion or contraction of the weld and base. A characteristic common to practically all hard-facing materials is that at normal temperatures they are relatively brittle and have a tendency to crack rather than yield through plastic flow when thermal stresses exceed their yield point. For this reason consideration must be given to the thermal gradients involved during welding; and, as will be seen later, the properties of the base metal in this respect also assume great importance.

Another cause of thermal stresses sometimes may be different coefficients of expansion in the hard-facing alloy and the base metal. To minimize this, the expansion coefficients of the facing and base metal should be matched as closely as possible.

Corrosion—

Most of the alloy hard-facing materials are satisfactory for resisting many corrosive conditions, but corrosive agents encountered in hard-facing applications are too varied to permit specific discussion. In addition, the concentration of any one corrosive agent and its temperature may vary widely for different applications and thus present different corrosion resistant requirements.

Thus, in selecting hard-facing alloys one must know the specific corrosive agent involved, and its concentration and approximate temperature. Corrosion tables should be consulted, as should manufacturers of hard-facing materials. If no data are available, tests can be run by applying several layers of the hard facing in question to a strip of metal not affected by the corrosive agent and then subjecting it to the corrosive conditions encountered in actual service.

In general, the alloys in Group IA are more corrosion resistant than most low alloy steels, but cannot be considered as stainless. Group IB alloys are similar to stainless steels in their corrosion resistance. Group II alloys have the best corrosion resistant characteristics at normal as well as elevated temperatures.

Erosion—

In parts, such as valves and water wheels, anti-erosion properties in hard-facing materials are of prime importance. The requirements of materials for such service are high hardness at normal and elevated temperatures, high polish, resistance to scoring and galling, and resistance to corrosion. The alloys of Group II possess this combination of properties and therefore are most satisfactory. Some of the high chromium alloys in Group IB also have these anti-erosion properties to a somewhat less degree, and so should also be considered where erosion service is not too severe.

Design Considerations

In planning to apply a hard facing to a particular part it is often necessary to consider such things as the composition of the part and its size, also the thickness of deposit and the finish required. These factors may be quite important in selecting a hard-facing material; in some cases one or more of these might be the controlling factor.

Composition of Base Material—Practically all ferrous metals can be hard faced. Because of the lower melting points of nonferrous alloys, with few exceptions, they cannot be satisfactorily hard faced.

In ferrous metals it is usually most desirable to choose a low or medium carbon steel base wherever possible. If the carbon content is too high—above about 0.50%—the base may crack or become brittle from the heat of the welding operation. A low carbon steel base is also desirable for minimizing the effect of thermal stresses set up by welding in the hard-facing alloy. Being quite ductile, low carbon steels can relieve thermal stresses by deforming and thus avoid cracking of the weld which is usually comparatively brittle.

When possible, the base metal should be chosen with the service conditions in mind just as they are considered in selecting the hard-facing material. There is sometimes a tendency to place too much dependence on the hard facing. In some applications low carbon steels are not suitable, such as shear blades, certain types of dies and other parts which are subjected to severe pressures. In such cases higher carbon or alloy steels are required to insure greater stiffness and strength.

Below, the various materials that can be hard faced are listed and discussed in more detail.

Low and Medium Carbon Steels—Steels up to 0.50% carbon in hot or cold rolled form or as castings are especially suited to hard facing. Heat

Tractor rollers are being reclaimed here through application of a hard-facing alloy. The jig rotates the rollers during application of the metal. (Courtesy: Stoody Co.)

treatment either before or after welding is not required.

High Carbon Steels—With reasonable precautions, to prevent cracking, successful hard facing can be accomplished on carbon steels having as high as 1.10% carbon and 1.25% manganese. It is always necessary to hard face the material in an annealed or as-rolled condition. After welding and before the weld has cooled, the part should be reheated to around 1600 F and cooled in air. Either arc or gas welding may be used.

Low Alloy Steels—The hard-facing procedure is similar to that for plain carbon steels. The material should be in the annealed condition, and depending upon the composition, heat treatment is required after welding.

High-Speed Steels—These are not generally recommended as a base for hard facing because of the occurrence of shrinkage cracks and strain checks. Where absolutely necessary to hard surface high-speed steels, the part should be in the annealed state, and after welding should be reheated and cooled slowly.

High Chromium Alloy Steels (3 to 12%)—They are extremely susceptible to heat in any form and so must be handled with great care. Before facing, the part should be preheated to around 1200 F. After application cooling should be retarded.

Manganese Steel (10 to 14%)—Since the grain structure of manganese steel is easily disrupted by heat, these steels are difficult to hard face satisfactorily. Welding should be done by the electric arc method and great care taken to avoid overheating. The hard metal should be deposited in small areas as far removed from one another as possible to avoid concentration of heat at any one point. Practically any type hard-facing alloy can be used. It is sometimes advisable to apply a layer of stainless steel first as a binding agent. Manganese steel can often be surfaced to advantage with an austenitic rod, to give a work hardening deposit.

Stainless Steels—They may be hard-faced by either arc or gas methods and should generally be preheated. The particular physical properties of the type stainless should be known to avoid excessive strains, brittleness or decreased corrosion resistance from welding.

Cast Irons—Cast irons present considerable difficulty in hard facing. For gray cast iron, the procedure is somewhat different from that of steel, because of the lower melting point of cast iron and crust formation on the iron surface. Care must also be taken to avoid localized overheating of the iron. The procedure for alloy cast irons is the same as for gray cast irons. White or chilled iron can be easily hardened in small parts, but on larger parts heat treatment is often necessary.

Nonferrous Alloys—It is not advisable to hard face alloys with melting points below 2000 F. Thus, copper and its alloys, brass, and bronze, with their low melting point and high heat conductivity, are hard faced only with difficulty. Monel metal, being without these limitations, can be easily hard faced.

Surface Finish—The smoothness of the weld depends upon the hard-facing material, the welding method, and the welder. Materials with the highest fluidity give the smoothest deposits. Thus, Group II alloys can produce the smoothest and thinnest deposits. Group IA alloys will also acquire a smooth finish with a high polish.

The roughest finishes are obtained with the materials in Group III. Both the insert and composite forms of tungsten carbides give a rough surface. However, if the carbide particles are very fine and are completely submerged in the matrix alloy, the original finish may be quite smooth; of course, in service, the softer matrix will wear first and soon expose the rough harder carbide particles.

Thickness of Deposit—In hard-facing applications the thickness of deposits range from 1/16 to ¼ in. Most seem to average around ⅛ in. but, of course, the proper thickness depends upon the specific application. Parts that require a build-up greater than ¼ in. are usually rebuilt before hard facing with a lower cost material, often alloys of Group I. The hardness of such under-layers may be around 300 to 450 BHN.

Where applicable a mild steel filler rod or shape can be used to serve as a base for the hard facing. In other cases inserts of the appropriate hard-facing material may be more practical than building up a thick section.

Where an extremely thin layer is required, those alloys with high fluidity, Group II, are best. Some of these nonferrous alloys will "wet" the base metal so readily that a uniform deposit of 1/32-in. thick is possible.

Size of Part—The size of the part may sometimes be a consideration. Where very large, the cheaper hard-facing alloys are given preference. The size of the part is also a consideration in selecting the rod size. Since larger diameter rods cut down on labor cost, the largest diameter rod that can be deposited satisfactorily should be used.

The overall cost of hard facing includes the costs of preparation, welding, and finishing, and the cost of the hard-facing material. For any particular welding method, the processing costs, such as preheating, welding sup-

plies, jigs and fixtures, and finishing, are essentially the same regardless of what hard-facing material is used. So, a very important cost consideration is the hard-facing material.

The cost of the various hard-facing alloys varies considerably from as low as fifty cents up to six dollars per lb. Group IA alloys are the least expensive, and following in order of increasing cost are Groups IB, II, and III.

From all that has gone before it is obvious that a hard-facing material should not be chosen solely on a price basis. There are often service conditions besides abrasion that determine the selection regardless of cost. For example, where such things as special corrosion conditions, heat or thermal shock, or galling are encountered, the selection is limited to certain alloys; others which may be lower in cost simply cannot be considered because they cannot meet the imposed service conditions.

But where a number of different alloy types, having varying prices, can be used, to increase the wear life of a part, the question of cost assumes greater importance. Selection then depends upon weighing a number of cost factors and thus arriving at the most economical hard-facing material. For one, the useful life of the part being hard faced should be considered. If the part itself has a short life it would not be economical to hard face the surface with a high cost alloy that would outlive many times the service life of the part. A cheaper alloy having approximately the same life as the part itself should be selected.

If a part has a long life and will require repeated applications of hard surfacing, selection of the facing material rests upon a number of things. The different wearing lives of the various alloys must be balanced against their cost. If in a particular job alloy *A* outwears alloy *B* 2 to 1, and the price of alloy *A* is only half again as much as alloy *B*, the choice would, of course, be alloy *A*. Another important factor in such cases is the labor and processing costs. The use of a very high-priced facing is often justified where the cost of repeatedly applying a cheaper and less wear-resistant alloy exceeds the cost of the high-priced alloy.

There are other considerations such as the time the part is out of service while being hard faced, and the time and cost of dismantling the part for facing and then remounting it. These may or may not be important, depending upon the application.

The area to be covered is also a factor. If only a small amount to surface a small area is required, the best grade facing available is usually selected; however, where very large areas are concerned the material cost using higher priced alloys often becomes prohibitive.

Processing Considerations

To select a hard-facing material properly some thought must be given to the welding characteristics of the various alloys, also how they can be finished and whether or not they can be subsequently heat treated or hot worked. Just as with design considerations, one or more of these factors may limit the possible hard-facing choice regardless of the service properties that are desired.

Machining, Grinding and Hot Shaping—Since hard-facing materials are purposely designed to be hard and abrasion resistant, they are obviously difficult to finish. So in planning for hard facing, thought should be given to avoiding finishing operations wherever possible.

Where finishing is required, grinding is probably the method most often used. Where machining must be done, it is best to choose a hard-facing material that is soft enough in the as-welded condition, or one which can be annealed for machining and then satisfactorily rehardened. Alloys that can be machined after welding without a softening operation are in the form of drawn electrodes giving weld deposits in the low and medium carbon range (0.30 to 0.40%).

Alloys of Group IA and IB are ordinarily difficult to machine. Group IA alloys can be shaped by hammering, scraping or hot filing when raised to around 200 to 300 F. Group IB alloys, being less ductile, cannot be hot shaped as easily and must usually be ground.

The softer alloys of Group II with hardnesses around 43 Rockwell C are machinable with carbide tools. All of them can be finished by grinding. The wheel speed when grinding these alloys must be watched to avoid grinding checks. The range of wheels speeds runs from around 2800 to 4200 surface ft. per min. Group II alloys cannot be readily hot filed or forged.

The materials in Group III can only be finished by grinding. The grinding wheels should be designed for this particular work.

Rewelding Hard Facing—Often in hard-facing applications it is planned to reweld over the original hard facing after it has begun to wear away. In such cases the weldability of the original hard facing, which will later become the base metal, must be considered.

Too high carbon must be avoided in the original hard-facing alloy, for it may cause brittle carbides to form between the original and subsequent hard-facing deposit. Such carbide precipitation can cause spalling if impact is present. Low tensile strength is another cause of spalling between hard-facing layers.

Where high wear resistance is required, the carbon can be kept low by obtaining hardness and resistance to abrasion through addition of other elements or by using tungsten or other carbides in a tough, hard matrix.

Heat Treatment of Hard Facings—In general, most hard-facing alloys do not require heat treatment to achieve optimum wear characteristics. When heat treatment of parts after hard facing is required and the hard-facing alloy is heat treatable, it should have the same heat-treating cycle as the base material. It is important, of course, that the hard facing retain its wear-resistance qualities when it is necessary to heat treat the part. This does not mean that the facing and part being faced must be of the same analysis. It is often possible through heat treatment to obtain required wear characteristics with several different compositions.

Alloys in Group I having austenitic

matrices are not heat treatable. Thus, most of the Group IB alloys, which contain very high percentages of chromium, are austenitic and cannot be heat treated. The alloys having a martensitic or pearlitic type matrix are heat treatable and the majority of alloys with these structures will be found in Group IA. However, there are austenitic iron-base alloys in this group and these are not susceptible to heat treatment.

Group II nonferrous alloys are not affected by heat treatment. Group III alloys may or may not be heat treatable, depending upon the structure of the matrix binder which holds the hard carbide particles. If the matrix has an iron base with an austenitic structure, it is not heat treatable; if of the martensitic type, it can be heat treated.

The ability to be heat treated is a desirable characteristic when finishing operations such as machining are required. In such cases the part can be annealed for finishing and then rehardened to give it its wear characteristics.

Welding Method — Practically all hard-facing materials can be deposited by any of the common welding methods. However, with some of the groups one method of application is preferable to another. The Group IA and IB alloys can be deposited satisfactorily by either arc- or gas-welding methods. With these alloys, the part to be hard faced is actually fused and the welding rod melted upon it. For gas welding the rods are usually bare, while for arc welding they are furnished bare and flux coated.

The nonferrous alloys, Group II, are more adaptable to gas welding than to electric arc welding. The application of these rods with the oxyacetylene torch is similar to a brazing operation. The surface to be faced is heated to a sweating temperature (around 2200 F) and then the welding rod is melted and flowed over the sweating surface. Ease of application of these alloys results from their relatively low melting point and their high fluidity at molten temperatures. They make a bond with the base metal that is actually stronger than the alloy itself.

The tungsten carbides in the form of rods can be deposited by either gas or metallic arc methods. The cast rod form, however, is best applied by the oxyacetylene process and the rod should be melted over the fused surface of the part without penetrating deeply into it.

Insert forms are applied with gas welding by puddling the surface to be faced and then setting the inserts in place in the molten metal. The inserts can be overlayed by either gas or arc welding. Insert shapes are also emplaced by fastening them to the surface by metallic arc welding.

Although this manual is concerned principally with hard-facing materials and their selection, a brief discussion of welding methods commonly used for hard facing will be given, because the method, independent of the material, often influences the characteristics of hard-facing deposits. For example, cooling hard-facing deposits after solidification is actually a heat treatment and therefore affects the final structure and properties of the facing. And cooling rates of welds are directly influenced by the welding procedure used. Welding methods are also important in considering such things as weld finish, speed of application, and size and shape of parts being faced.

The two chief welding methods for applying hard-facing materials are metallic arc welding and oxyacetylene welding. Electric arc welding is generally the most economical method. It is rapid and can be used to advantage where thick layers are required on large areas. It provides the most intense source of heat and rapidly melts the hard-facing rod and fuses it to the base material.

In arc welding the fused surface layer of the base metal mixes with the hard-facing deposit and tends to modify its composition and sometimes its structure. Because of this, the hard-facing characteristics of the deposit may be adversely affected. Often hard-facing electrodes are designed to compensate for this dilution effect, but such compensation can only allow for average conditions of deposition.

Rapid and concentrated heat input associated with arc welding may make it an undesirable method in some applications, because of the sharp temperature gradients involved both during welding and cooling. Very rapid heat input in a welding operation results in restricted local heating and rapid cooling of the weld deposit; and this, through expansion and contraction stresses, may cause cracking. Also, in certain applications such as hard facing heat treated austenitic manganese steel, embrittlement of the base metal will result from localized heating. So, when hard facing on hardenable materials—*i.e.*, whenever carbon exceeds 0.25% in mild steels or 0.12% in low alloy steels—it is usually necessary to preheat the base material before arc welding to avoid cracking. It is also desirable when thicknesses exceed 2 in.

Gas welding provides a less intense flame than arc welding, and the nature of the process automatically provides for preheating which minimizes thermal gradients adjacent to the weld. Since the heat input rate is slower and the base material absorbs a large portion of it, the cooling rate of weld is slower than for arc welding. This is a distinct advantage for welding on hardenable metals. With gas the heat input for welding is greater than in arc welding, and so distortion will be more.

With oxyacetylene welding good bonding is obtained with a minimum of weld penetration into the base material. In many applications the hard-facing material is "sweated" to the base metal. This results in minimum dilution of the weld deposit with the base material. Gas weld deposits are somewhat smoother than arc deposits. On thin sections gas is preferred to arc welding because the flame is not as intense and there is greater control over the heat input.

When hard facing by the oxyacetylene process, a neutral flame or one with an excess of acetylene is usually used. If an excess of oxygen is allowed, metal oxides may form by reaction with the deposited metal and give the deposit inferior abrasion resistance.

Besides gas and electric arc welding, atomic hydrogen and inert-gas-shield-arc welding methods are occasionally used for hard facing. Recently the submerged melt welding process has seen some use in building up and surfacing parts with dissimilar materials. These methods will see continued development in the future for hard-facing applications.

Methods of applying hard-facing materials in powder form have been developed and are now seeing use for certain applications. The methods involve spraying the surface with the facing powder using a regular metallizing gun or a special powder torch, and then fusing this powder overlay with either an oxyacetylene flame, induction heating equipment or a controlled atmosphere furnace.

The advantages of such processes are: (1) no porosity in the facing, (2)

Table II—Wet Sand Abrasion Resistance of Some Hard Facing Materials Arranged in Order of Wet Quartz Sand Abrasion Resistance

Hard Facing Group[1]	Analysis[2]	Composition, Percent											Weld Type	Rc	Abrasion Factor
		C	Mn	Si	Ni	Cr	Mo	W	Co	B	V	Others			
III	D	Mosaic of cemented tungsten carbide insets											Gas	—	0.17
IA	D	Martensitic cast iron weld deposit											Gas	62	0.41
												Fe%			
II	R	2.67	1.56	0.89	—	30.9	—	14.0	45.5	—	—	3.6	Gas	56	0.49
IA	R	3.71	0.15	0.63	—	7.44	1.82	—	—	—	—	—	Arc	60	0.51
IB	R	3.48	0.26	1.19	—	8.09	2.98	14.9	—	—	—	—	Arc	64	0.52
IA	R	3.16	0.20	0.81	—	4.27	4.21	—	—	—	—	—	Gas	60	0.53
IB	R	5.28	0.21	2.32	6.39	15.54	8.51	—	—	—	—	—	Arc	65	0.54
IA	R	3.72	1.96	1.68	—	9.15	1.83	—	—	—	—	—	Arc	62	0.54
II	R	2.67	1.56	0.89	—	30.86	—	14.0	45.5	—	—	3.6	Gas	56	0.54
—	D	Martensitic steel weld deposit											Gas	59	0.55-0.57
IB	R	1.24	1.63	1.23	0.30	27.48	4.03	—	—	—	—	—	—	53	0.57
IA	R	3.52	3.02	1.89	—	6.34	1.73	—	—	—	—	—	Arc	61	0.59
IB	R	2.62	3.62	1.02	—	31.76	—	—	—	—	—	—	Arc	60	0.59
II	R	2.60	3.50	1.00	—	31.68	—	14.12	43.1	—	—	4.1	Arc	59	0.61-0.62
IA	R	3.71	0.14	1.17	—	7.05	1.93	—	—	—	—	—	Arc	58	0.61
IA	R	3.16	0.35	1.91	1.15	3.45	4.02	—	—	<0.01	<0.01	—	—	63	0.64
IA	R	3.07	0.18	0.88	3.87	1.27	—	—	—	—	—	—	Arc	59	0.66
IA	D	3.19	0.20	1.24	—	7.61	2.04	—	—	—	—	—	Arc	60	0.66
II	R	1.06	—	2.12	—	28.33	—	5.25	61.0	—	—	—	Arc	43	0.66
IA	R	0.89	0.88	1.53	—	4.15	6.97	5.13	—	—	1.07	—	Gas	63	0.67-0.77
					(High-speed)										
IA	R	0.72	0.64	1.26	—	4.32	7.10	4.82	—	—	0.98	—	Arc	62	0.67
					(Steel type)										
IA	R	3.55	1.85	1.19	—	11.54	—	—	—	—	—	—	Arc	55	0.67
IB	R	4.21	0.21	0.89	6.34	16.06	8.61	—	—	—	—	—	—	60	0.69
IA	R	3.71	0.14	1.17	—	7.05	1.93	—	—	—	—	—	Arc	56	0.69
IA	R	3.55	1.85	1.19	—	11.54	—	—	—	—	—	—	Gas	55	0.69-0.74
IA	R	3.07	0.18	0.88	3.87	1.27	—	—	—	—	—	—	Arc	57	0.70
II	R	2.64	1.52	0.89	—	30.71	—	13.95	45.5	—	—	3.62	Gas	55	0.71-0.73
IA	R	1.27	—	0.76	—	5.87	1.96	—	—	—	—	—	Gas	34	0.71
IA	R	3.59	1.87	1.67	—	8.83	—	—	—	—	—	—	Gas	56	0.73-0.76
IA	D	0.89	0.57	0.73	0.20	11.74	0.10	—	—	—	—	—	Arc	36	0.75
IA	R	3.82	0.43	1.10	—	7.56	1.99	—	—	—	—	—	Gas	58	0.74
IA	R	3.59	1.87	1.67	—	8.83	—	—	—	—	—	—	Arc	55	0.75
IA	R	1.00	0.65	0.38	—	5.50	1.00	—	—	—	0.25	—	Arc	67	0.76-0.78
IA	D	0.46	0.21	0.30	—	4.11	1.55	—	—	—	0.15	—			
IA	R	0.81	—	—	—	4.0	8.50	1.25	—	—	1.15	—	Arc	44	0.77
IA	R	0.95	—	—	—	4.0	5.25	5.75	—	—	1.60	—	Arc	40	0.77
IA	R	0.95	—	—	—	4.0	8.50	1.25	—	—	—	—	Arc	36	0.77
II	R	2.19	—	1.55	—	27.33	—	10.6	54.2	—	—	—	Gas	57	0.78
IA	R	0.53	0.63	0.19	0.05	1.00	0.01	—	—	0.01	0.01	—	—	27	0.80
IA	R	3.88	1.97	1.42	—	11.77	—	—	—	—	0.31	—	Gas	56	0.85-0.86
												Cu%			
IA	R	0.80	14.01	0.77	—	—	0.22	—	—	—	—	0.18	Arc	21	0.86
												Fe%			
II	R	2.82	0.20	0.86	—	31.83	—	13.86	46.48	—	—	3.30	Gas	56	0.89-0.91
II	R	1.41	—	1.83	—	27.27	—	7.09	58.1	—	—	—	Gas	50	0.92
Rolled Steel Standard		0.20	0.45	0.07	—	0.08	—	—	—	—	—	—	—	—	1.00
IA	R	3.87	1.40	1.02	—	—	2.17	—	—	—	—	—	Arc	52	1.02
II	R	1.06	—	2.12	—	28.33	—	5.25	81.0	—	—	—	Gas	50	1.03
II	—	1.04	3.52	1.59	—	27.56	—	3.52	60.0	—	—	1.86	Arc	48	1.03
IA	R	3.83	1.84	1.20	—	—	7.16	—	—	—	—	—	Arc	47	1.05
II	R	2.19	—	1.55	—	27.33	—	10.6	34.20	—	—	—	Gas	42	1.08
IA	—	0.67	14.6	1.11	—	—	1.04	—	—	—	—	—	Arc	—	1.22-1.29
												Cu%			
IA	R	4.04	0.67	3.33	—	—	2.25	—	—	—	—	0.22	Arc	39	1.38

[1] IA—Iron base—less than 20% alloy.
IB—Iron base—more than 20% alloy.
II—Nonferrous alloys.

[2] R—Chemical analysis of rod.
D—Chemical analysis of deposit.

Data from "Hard Surfacing by Fusion Welding" by H. S. Avery, published by American Brake Shoe Co.

deposit is smooth and uniform, and (3) they are rapid and economical. The limitations are: (1) cannot be used to deposit less than 0.010 in. and greater than 0.050 in. in thickness; (2) at present only a few hard-facing materials are available in powder form; and (3) on small pieces the heat used to fuse the powder overlay may reduce some of the mechanical properties of the base metal.

Another process now seeing limited use has been developed in which the powdered hard-facing alloy is applied directly to the surface without the use of a metallizing gun or being mixed in a paste.

Mechanization of hard-facing methods should be considered wherever large quantities of parts are being faced. By mechanization the hard-facing cost per part may be reduced because fewer operators are required. The hard facing is usually more uniform and the operation can be performed much more rapidly. Whether or not mechanization is feasible depends upon the size and shape of the parts, ease of handling, distribution of hard-faced areas, and type of deposit.

Acknowledgement

The cooperation of all manufacturers of hard-facing materials in supplying data on their products is acknowledged. The following companies supplied additional data and information for this manual:

Air Reduction Sales Co.
The American Brake Shoe Co.
Haynes Stellite Co.
Metal & Thermit Corp.
Stoody Co.

(Continued on page 116)

Directory of Hard-Facing Materials

Company	Trade Name	Alloying Elements	Type	Uses and Remarks
Air Reduction Sales Co.	Airco #91	Manganese, chromium, silicon	IA	For resistance to sliding abrasion and shock
Allis-Chalmers Mfg. Co.	X-1	—	I	For abrasion and mild impact. Rc 56-60
	X-2	Chromium, molybdenum	I	Resistance to abrasion, erosion and mild impact. Rc 47-55
	X-3	Chromium, molybdenum	I	Resistance to severe abrasion, erosion and impact. Rc 51-59
Alloy Rods Co.	Mang-Arc	Manganese, nickel	IA	Austenitic. For nickel-manganese (13%) parts
	Wear-Arc "600"	Manganese, chromium, molybdenum, silicon	IA	Rc 59
	Wear-Arc "500"	Manganese, chromium, molybdenum, silicon	IA	Rc 51
	Wear-Arc "400"	Manganese, chromium, molybdenum, silicon	IA	Rc 40
	Wear-Arc "300"	Manganese, chromium, molybdenum, silicon	IA	Machinable. Rc 32
American Manganese Steel Div., American Brake Shoe Co.	Resistwear	Chromium, molybdenum, manganese	IA	Martensitic steel. Abrasion and impact resistant. Rc 43-53
	Economy Hardface	Chromium, molybdenum	IA	For machine parts subject to high impact and abrasion. Rc 45-50
	Toolface	Chromium, molybdenum, tungsten, vanadium	IA	For cutting tools and dies. Rc 55
	Amsco #217	Tungsten, chromium, molybdenum	IB	High abrasion resistance up to 1000 F. Martensitic iron. Rc 60-65
	Amsco #459	Molybdenum, chromium, nickel, manganese, silicon	IB	High abrasion resistance up to 800 F. Martensitic iron. Rc 55-60
	Farmface	Chromium, molybdenum, nickel, silicon	IA	For agricultural parts. Martensitic iron. Rc 55-60
	Nickel-Manganese Steel	Manganese, silicon, nickel	IA	For austenitic manganese steel castings
	Amsco #6	Cobalt, chromium, tungsten, manganese	II	High resistance to abrasion and corrosion at high temperatures. Rc 44-45
	Amsco #1	Cobalt, chromium, tungsten, manganese.	II	High resistance to abrasion and corrosion at high temperatures. Rc 54-55
	Amsco Ni-Hard	Nickel, chromium	IA	For extreme wear. Martensitic iron. Rc 50-55
	Machine-Face	Chromium, manganese	IA	Machinable. Can be flame hardened. Rc 34-37
	Railface	Chromium, molybdenum	IA	For carbon steel rail ends. Rc 34-37
	Mang-Co	Manganese, silicon	IA	Austenitic steel. Work hardens to Rc 43-47
	Mo-Mang	Manganese, silicon, molybdenum	IA	Austenitic steel. Work hardens to Rc 47-51
Arcos Corp.	Manganend 13 Shielded Arc	12 to 14% nickel, manganese	IA	For dissimilar metals where impact is present
	Chromend 12C	12% chromium, high carbon	IA	For valve seats
	Chromend 12	12% chromium	IA	For turbine blades and valve seats
Bergstrom Alloys Corp.	Bergstrom Type "S"	Manganese, nickel	IA	Low-priced work hardening rod. Rc 29-31
	Mangaloy	Manganese, nickel, chromium	IA	For manganese steels
	Trakaloy	Titanium, manganese, nickel, chromium	IA	For rails and wheels. Good ductility. Rc 30
	Supraloy	Boron, iron	IB	For metal to metal wear. Rc 62-64
	Flexaloy	Chromium, manganese, nickel	IA	Rc 55. Wear resistance good against earth
	Ranalloy Type "C"	Molybdenum, nickel, chromium	IA	Rc 46-48. Can be forged and ground
	Ranalloy Type "B"	Molybdenum, nickel, chromium	IB	Rc 53. Greatest wear resistance of Bergstrom alloys
	Ranalloy Type "A"	Molybdenum, nickel, chromium	IB	Rc 50. Can be forged, takes high polish
Callite Tungsten Corp.	No Wear	Tungsten, cobalt, iron, chromium, carbon	—	—
	Railend	—	IA	For rail ends
	Hard Devil	—	IA	For car wheels, rail ends, road building equipment
	Tough Devil #1	Manganese, nickel	IA	For manganese steel parts
	Tough Devil #2	Manganese, molybdenum	IA	—
	Wear Devil "A"	—	—	For abrasion, erosion and corrosion
Champion Rivet Co.	Wear Devil "B"	—	—	For high abrasion and impact
	Plowface	—	IA	For agricultural equipment
	#59	—	IB	For manganese and high carbon steel
	#48-1	—	—	For high abrasion, little shock or impact. Rc 55
	#64-6	—	—	Good for hot punches, hot trim dies, and valve seats. Rc 42
	#58-12	—	—	For high abrasion and impact. Rc 50
Coast Metals, Inc.	#1 and 101	Chromium, nickel	IB	File hard. Rc 45-55
	#4 and 104	Chromium, nickel, silicon	IB	Good for acetylene deposits on cylindrical sections. Rc 55-60
	#112	Chromium, nickel, molybdenum, titanium	IB	For earth moving equipment. Rc 53-59
	#18 and 118	Chromium, nickel, molybdenum, cobalt	IB	For valves, hot dies, punches. Rc 42-47
	#8 and 108	Chromium, nickel, cobalt	IB	For cold shearing and stamping. Rc 45-53
	#9 and 109	Chromium, nickel, molybdenum, silicon	IB	For hot mill shoes
	#15 and 115	Chromium, nickel, molybdenum, cobalt, silicon	IB	Hard, tough. High temperature properties Rc 55-60
	#7 and 107	Chromium, nickel, molybdenum	IB	Soft and tough. For chip crusher hammers. Rc 35-45
	#10 and 110	Chromium, nickel, molybdenum	IB	Hard. Moderately high temperature properties. Rc 52-60
	#40 and 140	Chromium, nickel, cobalt, tungsten	II	Good high temperature properties
Delloy Metal Corp.	Delloy	—	—	For all kinds of steel. Rc 58-60
Dymonhard Corp. of America	Dymonhard #55	Chromium, nickel, low carbon	IA	Work hardening. Can be forged and shaped
	Dymonhard #65	Molybdenum, tungsten, chromium	IA	Air hardening, drawn rod
	Dymonhard #95	High carbon, molybdenum, manganese, chromium	IB	Rc 59-64. Low cast alloy
	Dymonhard #94	Chromium, nickel, molybdenum	IB	Rc 56-57. For abrasion and shock when heat is present
	Dymonhard #93	Chromium, nickel, tungsten	IB	Rc 57-59. Resists many dilute or concentrated acids
	Dymonhard #92	Chromium, nickel, molybdenum, tungsten	IB	Rc 58-59. For use in presence of corrosion and dilute chemicals
	Dymonhard #90	High chromium, tungsten, molybdenum	IB	Rc 60-62. Has red hardness, highest abrasion resistance of Dymonhard alloys.
Fansteel Metallurgical Corp.	Fanweld	Cobalt, chromium, tungsten, tantalum, columbium	II	—
General Electric Co.	W-35	Low manganese	IA	Machinable. For surfaces requiring somewhat greater abrasion resistance than mild steel
	W-93	Chromium, manganese	IA	For rolling friction, moderate abrasion and high impact
Harnischfeger Corp.	Harnimang A & B	Manganese, nickel	IA	Approaches manganese steels in resistance to impact and abrasion. Rc 45-50 (work hardened)
	Harmomang A & B	Manganese, molybdenum	IA	Austenitic, for manganese steel. Rc 45-50 (work hardened)
	Abrasocote 20	Manganese, chromium, nickel	IB	Austenitic. For railway equipment and rails. Rc 25-35

Company	Trade Name	Alloying Elements	Type	Uses and Remarks
Harnischfeger Corp. (Cont.)	Abrasocote 10	Chromium, molybdenum	IA	For low alloy, high carbon, high manganese parts. Rc 35-40
	Hartung	Tungsten, molybdenum	IA	For rebuilding tools and dies. Rc 55-65
	Harcote 45	Chromium	IA	For high abrasion and impact. Rc 40-50
	Harcote 55	Chromium	IA	Semi-austenitic. For carbon steel low-alloy, and high manganese parts. Rc 50-60
	Harcote 35	High carbon	IA	For low and high carbon, and alloy steels. Rc 30-40
	Harcote 20	Medium carbon	IA	Machinable. For low abrasion
Haynes Stellite Co.	Composite Rod or Tube Rod	Tungsten carbide particles in tube or steel binder	III	Available with various screen sizes of carbide particles
	Haystellite Cast Inserts	Tungsten carbide	III	Hardest of Haynes Stellite alloys
	Hastelloy Alloy CHF	Nickel, molybdenum, iron	II	—
	Hascrome Rod	Chromium, manganese	IA	240 to 500 BHN as deposited. Work hardening.
	Alloy #93	Chromium, cobalt, molybdenum, vanadium	IB	Rc 62. High abrasion resistance, moderate impact resistance
	Alloy #6	Cobalt, chromium, tungsten	II	Rc 40. High abrasion resistance at elevated temperatures
	Alloy #12	Cobalt, chromium, tungsten	II	Rc 48. High abrasion resistance at elevated temperatures
	Alloy #1	Cobalt, chromium, tungsten	II	Rc 54. High abrasion resistance at elevated temperatures
	Hastelloy Alloy C	Nickel, molybdenum, iron, carbon	II	For hot work punches and dies, hot shear blades
	—	Tungsten carbide, Alloy #6 binder	III	—
	—	Tungsten carbide, Hastelloy C binder	III	—
Hobart Brothers Co.	Manganick Coated or Bare	Manganese, nickel	IA	For manganese steel parts. Rc 47-51 (work hardened)
	Tufanhard 600	Chromium, molybdenum	IA	For high abrasion and moderate impact. Rc 58
	Tufanhard 400	Chromium, molybdenum	IA	For moderate abrasion and high impact. Rc 42
	Tufanhard 250	Chromium, molybdenum	IA	Machinable. For moderate abrasion and high impact. Rc 24
	Hardfacer 11	Chromium, nickel	IA	For straight and medium carbon, and manganese steel. Rc 42-52
	Hardfacer 112	Chromium, nickel, molybdenum, titanium	IA	Same as Hardfacer 11, but harder. Rc 52-57
	Toolfacer	Chromium, molybdenum, tungsten, vanadium	IA	For cutting tools. Rc 57-64
	Mangamol Coated or Bare	Manganese, molybdenum	IA	For manganese and high carbon steels
Hollup Corp.	Sureweld H	12 to 5% alloy	IA	—
	Sureweld H1	15% alloy	IA	—
	Sureweld H2	18% alloy	IA	—
	National Economy	10% alloy	IA	—
	Sureweld TD	Over 2% alloy	IB	—
	National 459	—	II	—
	National 217	—	II	—
	National #6	—	II	—
	National #1	—	II	—
	National Toolface	—	II	—
	National Tube Diamond Metal	Tungsten carbides	III	Sized carbides in steel tube
Kerkling & Co.	Kerk-Aloy	—	—	—
Latrobe Electric Steel Co.	Red Arrow #48	Cobalt, chromium, tungsten	II	—
	Red Arrow #58	Cobalt, chromium, tungsten	II	—
	Red Arrow #64	Cobalt, chromium, tungsten	II	—

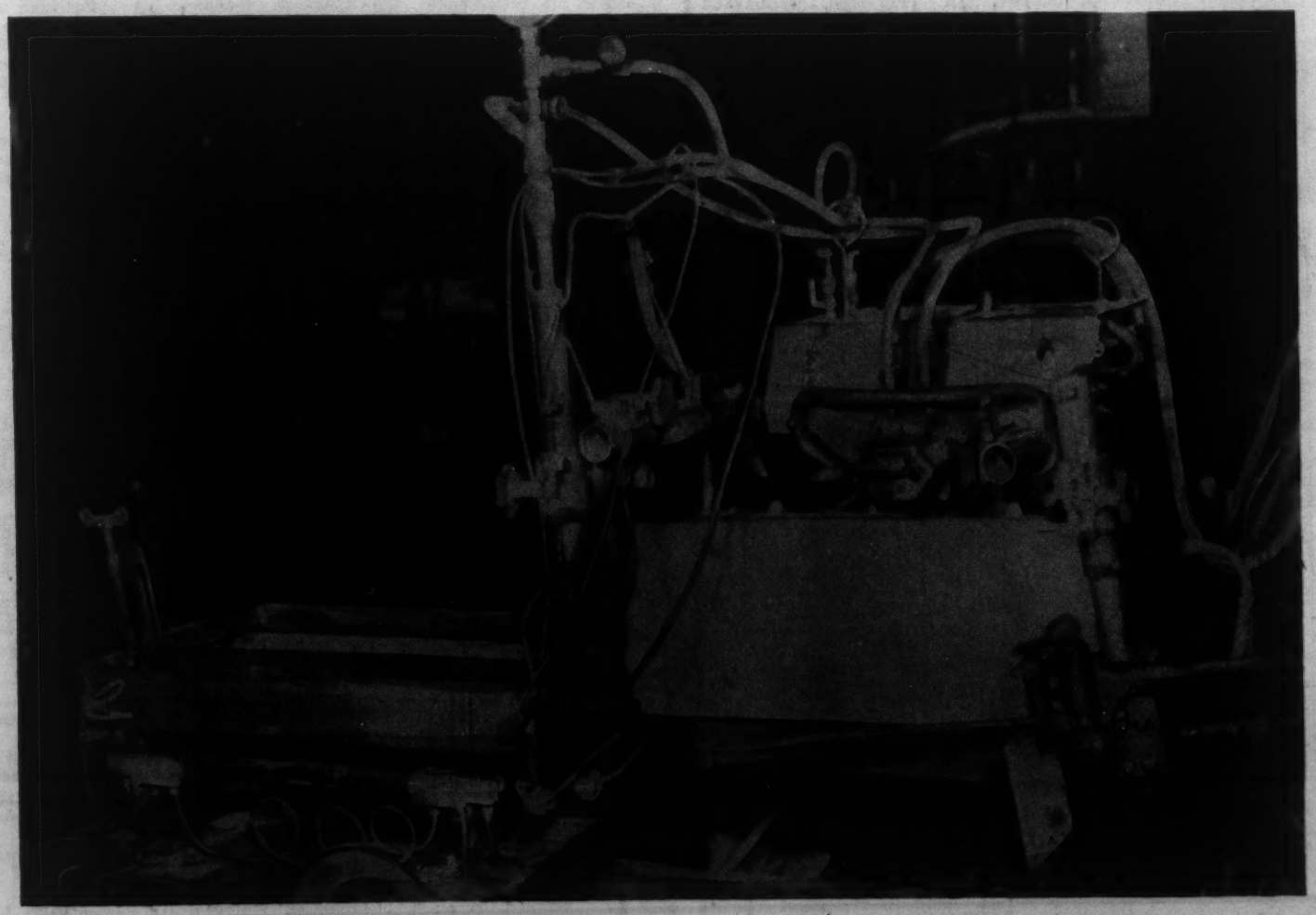
Company	Trade Name	Alloying Elements	Type	Uses and Remarks
Lincoln Electric Co.	Abrasoweld	—	IA	Semi-austenitic. For straight carbon, low alloy, and high manganese steel
	Wearweld	—	IA	Rc 50-55. For parts subject to moderate abrasion and high impact
	Hardweld 50	1.0% carbon	IA	Machinable
	Hardweld 100	1.0% carbon	IA	For moderate abrasion, high impact
	Manganweld B	Manganese	IA	For high manganese steel
	Manganweld A	Manganese	IA	For high manganese steel
	Surfaceweld	—	—	—
	Faceweld #1-2	—	IB	—
	Faceweld #12	—	IA	—
Marquette Manufacturing Co., Inc.	#650 Tool-Rod	Chromium, tungsten, vanadium, molybdenum	IA	For reclaiming parts of tool steels
	#550 Hard-Rod	Chromium, molybdenum, manganese	IA	For high abrasion and moderate impact
	#450 Hard-Rod	Chromium, manganese	IA	Alloys contained in coating. For high impact and abrasion
	#250 Mang-Rod	Manganese, nickel	IA	For manganese steel and for high manganese overlays in steel
	#110 Hy-Test-Rod	Chromium, molybdenum	IA	For high tensile steels subject to moderate abrasion and shock
	#100 Hard-Rod	Chromium, manganese, silicon	IA	For high carbon steels which may be subsequently forged and heat treated
McKay Co.	Hardalloy	Manganese, chromium, molybdenum, silicon	IA	Rc 59. For high impact and moderate wear
Metal & Thermit Corp	Murex Hardex 20	Chromium, manganese	IA	For moderate abrasion and high impact
	Murex Hardex 25	Chromium, manganese	IA	For moderate abrasion and high impact
	Murex Hardex 45	Chromium, manganese	IA	For high abrasion and moderate impact
	Murex Hardex 60	Chromium, manganese	IA	For high abrasion and moderate impact
Osage Metal Co., Inc.	Osage Amalgamated Rod	Tungsten carbide	III	Carbide particles mixed in a binding material
	Osage Tube Metal	Tungsten carbide	III	Carbide particles contained in a steel tube for extreme abrasion
	Osage "B" Hard-Facing Rod	—	—	—
	Osage Self-Hardening Rod	—	—	—
Rankin Manufacturing Co.	RanTung	Tungsten carbide	III	60% tungsten carbide particles in 40% tube binder
	Ranite C	Chromium	IA	Rc 60-62. For high abrasion
	Ranite B	Chromium	IA	Rc 44-50. General purpose hard-facing rod
	Ranite A	Chromium	IA	Rc 25-30. For high impact, moderate abrasion
Reid-Avery Co., Inc.	Raco 25	Chromium	IA	Machinable. Rc 20-25
	Raco 45	Chromium, manganese	IA	Harder and more resistant to abrasion than Raco 25. Rc 40-50
	Raco 55	Chromium, manganese	IA	Similar to Raco 45 but harder. Rc 50-60
	Racolloy Manganese	Manganese, nickel	IA	For manganese steel parts
Resisto-Loy Co.	Superloy	Chromium, molybdenum, cobalt, boron, tungsten, carbon	III	Hard synthetic particles in steel tube. Extreme abrasion resistance
	Tung-Alloy	Tungsten, molybdenum, cobalt, boron, carbon	IB	High resistance to wear, heat, impact
	Resisto-Loy	Chromium, molybdenum	II	High abrasion, corrosion and heat resistance
	Valve-Loy	Chromium, molybdenum, tungsten, cobalt, copper, boron	IB	For valve faces
	Isorod	Chromium, molybdenum, boron, titanium	IB	General purpose, self hardening

(Continued on page 118)

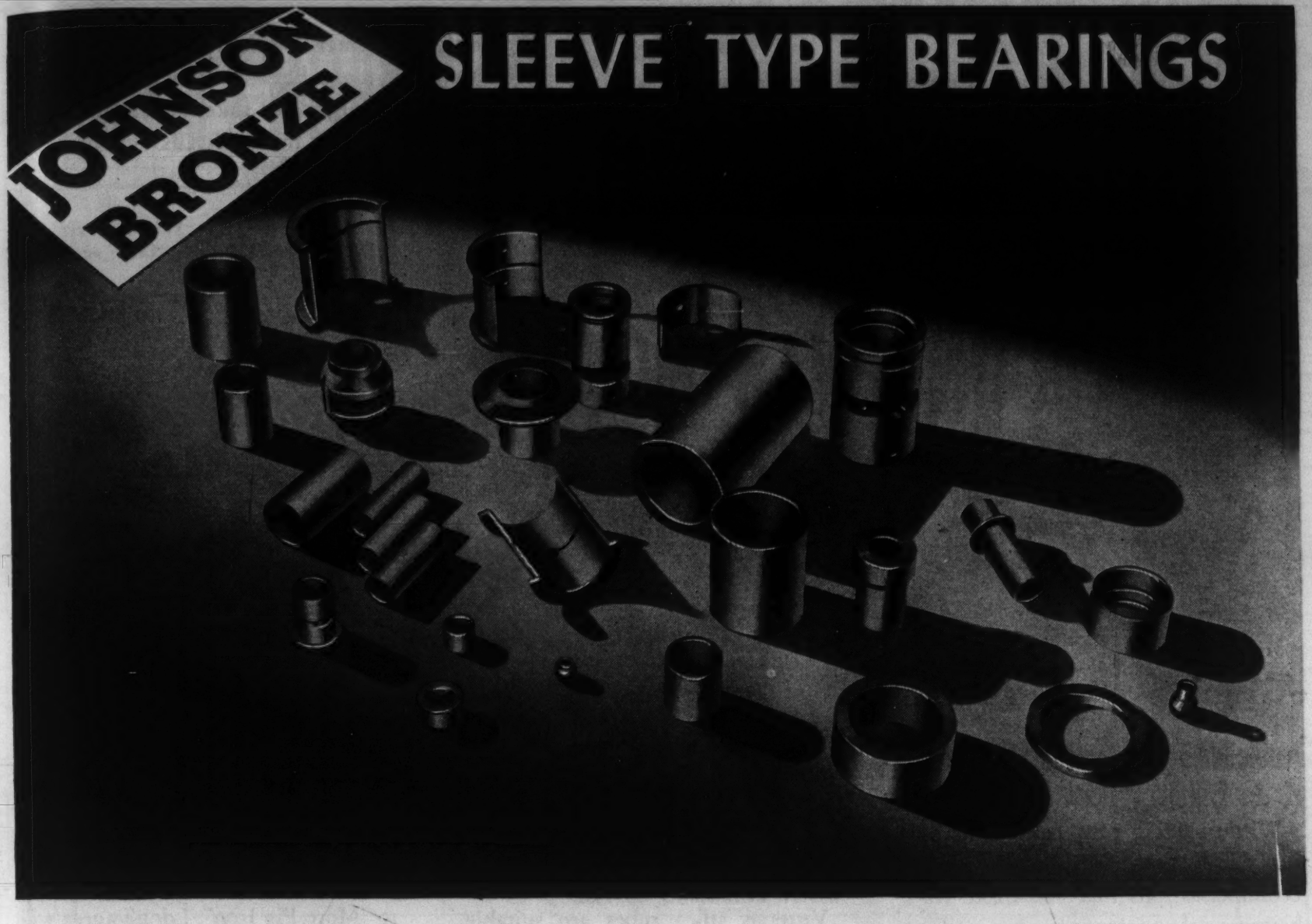
Directory of Hard-Facing Materials

(Continued from page 117)

Company	Trade Name	Alloying Elements	Type	Uses and Remarks
Resisto-Loy Co. (Cont.)	Flintype VH	Chromium, molybdenum, nickel, boron	IA	Low cost rod
	Two-Tone T. H.	Chromium, molybdenum, nickel, boron, titanium	IB	For "two-tone" process only; used with mild steel hot electrode
	Two-Tone H. C.	Chromium, nickel, molybdenum, vanadium, boron	IA	Special drawn wire for use in "two-tone" process
	Manga-Tone N. M.	Manganese, nickel, vanadium	IB	Nickel-manganese filler rod for use in "two-tone" process
Stoody Co.	Stoody Self-Hardening	Chromium, manganese, molybdenum, silicon	IA	Good abrasion resistance with high impact. Rc 52-54
	Stoodite	Chromium, manganese, zirconium, silicon	IB	High abrasion resistance. Rc 54-58
	Silfram	Chromium, nickel, silicon, carbon	IB	High wear resistance, good bearing surface. Rc 37-41
	Stoodex	Chromium, cobalt, tungsten, carbon	IB	Good wear resistance, smooth finish. Rc 49-51
	Stoodite 45	Chromium, molybdenum, tungsten, cobalt	IB	Retains wear resistance at red heat. Rc 45
	Stoodite 54	Chromium, cobalt, tungsten, molybdenum	IB	Retains wear resistance at red heat. Rc 54
	Stoodite 63	Chromium, molybdenum, tungsten, cobalt	IB	Retains wear resistance at red heat. Rc 63
	Stoody 1	Cobalt, chromium, tungsten	II	High abrasion and corrosion resistance at elevated temperatures. Rc 54
	Stoody 6	Cobalt, chromium, tungsten	II	High abrasion and corrosion resistance at elevated temperatures. Rc 41-43
Stoody Co. (Cont.)	Tube Borium	60% tungsten carbide, 40% steel	III	Various screen sizes of carbide particles in steel tubes. Extremely high abrasion resistance 9 to 10 on Moh's scale
	Borod	60% tungsten carbide, 40% steel	III	Same as Tube Borium except particles are 40 to 125 screen size
	Cobalt Borium Inserts	88% tungsten carbide, balance cobalt	III	Similar to Tube Borium, but in various insert shapes
	Borium Inserts	99% tungsten carbide	III	Inserts in a wide range of sizes
Wall-Colmonoy Co.	Colmonoy WCR-100	Chromium, tungsten, boron	IB	Withstands wear due to high pressures and shock. Rc 65-68
	Colmonoy #1	Chromium, boron, silicon	IA	For earth handling equipment. Rc 58-62
	Colmonoy #4	Nickel, chromium, boron, iron, silicon	II	For valves, dies and other parts which must be machined. Rc 35-40
	Colmonoy #5	Nickel, chromium, boron, iron, silicon	II	For parts that must be machined. High corrosion resistance. Rc 45-50
	Colmonoy #6	Nickel, chromium, boron, iron, silicon	II	High red hardness. Good resistance to galling and corrosion
	Colmonoy Sweat-on-Paste	Chromium boride	III	Boride particles held in a paste. Very high abrasion resistance. Rc 68-72



When quantities to be hard-faced are regular in outline and quantities are sufficient, automatic welding equipment can be applied. (Courtesy: Haynes Stellite Co.)



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CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

Protective Tubes for Thermocouples

To the Editor:

While reading your April issue of this year I noted with interest the recommendations that you make for thermocouple protecting tubes under various conditions.

We, as manufacturers of alloy steel tubing, are curious to know why stainlesses 309, 310 and 330 were omitted. We have sold many miles of tubing for many of the applications listed in the aforementioned alloys. Could it be that these were overlooked for some reason that we don't know anything about, or were they omitted just because the company which apparently made the list up is not acquainted with the alloys?

In any event, I do think it should be noted that the three alloys I mentioned are very much in demand and are very useful in this particular industry.

J. A. Deitrich, Asst. Mgr.,
Welded Alloy Tube Div.

The Carpenter Steel Co.,
Kenilworth, N. J.

To the Editor:

We have been much interested in the table on "Thermocouple Protecting Tubes," published on page 143 of your April issue, but regret that no mention is made of vitreous silica tubes which are largely used in both ferrous and nonferrous metallurgy as well as in the ceramic field for this purpose.

Vitreous silica tubes are suitable for use at temperatures up to 1850 to 2000 F, are extremely resistant to thermal shock, and recently have been found particularly valuable in connection with the "quick immersion" technique for ferrous metallurgy.

As pointed out by Ragatz and Hougen many years ago (*Chemical & Metallurgical Engineering*, 33:415 (1926), transparent vitreous silica protection tubes will stand even more severe conditions of use than the regular non-transparent quality.

Wm. W. Winship,
Manager

The Thermal Syndicate Ltd.,
New York, N. Y.

In the File Fact referred to in both of the above letters, we published the recommendations on materials for thermocouple protective tubes. Therefore, since no effort was made to list all possible materials for such applications, there were a few important items omitted, such as the stainless steel and vitreous silica tubes discussed here.—The Editors.

Idle Blast Furnaces

To the Editor:

I note your editorial in MATERIALS & METHODS of April 1947 referring to "More Pig Iron". I don't agree with your statement that capacity of present furnaces can be increased to any great extent by the use of oxygen, but I think someone of your standing should ascertain why—in this day of pig iron shortage—furnaces ready to operate are standing idle—in the hands of the W.A.A.

I refer to the

600-ton furnace at Chester, Pa.
890-ton furnace at Provo, Utah
1250-ton furnace at Donora, Pa.

There are doubtless others—these I am familiar with.

Wm. M. Kirk

448 Irvington Rd.,
Drexel Hill, Pa.

Perhaps producers are shying away from adding greatly to their capacity because of the fact that labor and other costs have risen to the point where operating at about 80% of capacity is necessary to break even. This is not a factor now, but it will be in the not-too-distant future. However, we do agree with Mr. Kirk that it is a sad situation in which we find ourselves—needing ever increasing quantities of pig iron but permitting furnaces to stand idle.—The Editors.

MATERIALS & METHODS Engineering File Facts

NUMBER 142
June, 1947

MATERIALS: Stainless and Heat-Resisting Steels

Standard Type Numbers, Chemical Composition Limits and Ranges for Stainless Steels

To meet the various requirements for applications of stainless and heat-resisting steel, a total of thirty (30) type analyses have been adopted as standards by the industry, each of which has distinctive characteristics which govern its application and use.

The chemical composition ranges given below are based on ladle analysis. Also given are the type numbers which are in use throughout the industry and which serve as a definite means of identification for the different grade classifications.

Type Number	Chemical Composition, Percent							
	C	Mn Max.	Si Max.	P Max.	S Max.	Cr	Ni	Other Elements
301	Over 0.08-0.20	2.00	1.00	0.040	0.030	16.00-18.00	6.00-8.00	—
302	Over 0.08-0.20	2.00	1.00	0.040	0.030	17.00-19.00	8.00-10.00	—
302B	Over 0.08-0.20	2.00	2.00-3.00	0.040	0.030	17.00-19.00	8.00-10.00	—
303	0.15 max.	2.00	1.00	—	—	17.00-19.00	8.00-10.00	P, S, Se min. 0.07, Zr, Mo max. 0.60
304	0.08 max.	2.00	1.00	0.040	0.030	18.00-20.00	8.00-11.00	—
305	0.12 max.	2.00	1.00	0.040	0.030	17.00-19.00	10.00-13.00	—
308	0.08 max.	2.00	1.00	0.040	0.030	19.00-21.00	10.00-12.00	—
309	0.20 max.	2.00	1.00	0.040	0.030	22.00-24.00	12.00-15.00	—
310	0.25 max.	2.00	1.50	0.040	0.030	24.00-26.00	19.00-22.00	—
314	0.25 max.	2.00	1.5-3.0	0.040	0.030	23.00-26.00	19.00-22.00	—
316	0.10 max.	2.00	1.00	0.040	0.030	16.00-18.00	10.00-14.00	Mo 2.00-3.00
317	0.10 max.	2.00	1.00	0.040	0.030	18.00-20.00	11.00-14.00	Mo 3.00-4.00
321	0.08 max.	2.00	1.00	0.040	0.030	17.00-19.00	8.00-11.00	Ti 5xC min.
347	0.08 max.	2.00	1.00	0.040	0.030	17.00-19.00	9.00-12.00	Cb 10xC min.
403	0.15 max.	1.00	0.50	0.040	0.030	11.50-13.00	—	Turbine quality
405	0.08 max.	1.00	1.00	0.040	0.030	11.50-13.50	—	Al 0.10-0.30
406	0.15 max.	1.00	1.00	0.040	0.030	12.00-14.00	—	Al 3.50-4.50
410	0.15 max.	1.00	1.00	0.040	0.030	11.50-13.50	—	—
414	0.15 max.	1.00	1.00	0.040	0.030	11.50-13.50	1.25-2.50	—
416	0.15 max.	1.25	1.00	—	—	12.00-14.00	—	P, S, Se min. 0.07, Zr, Mo max. 0.60
420	Over 0.15	1.00	1.00	0.040	0.030	12.00-14.00	—	—
430	0.12 max.	1.00	1.00	0.040	0.030	14.00-18.00	—	—
430F	0.12 max.	1.25	1.00	—	—	14.00-18.00	—	P, S, Se min. 0.07, Zr, Mo max. 0.60
431	0.20 max.	1.00	1.00	0.040	0.030	15.00-17.00	1.25-2.50	—
440A	0.60-0.75	1.00	1.00	0.040	0.030	16.00-18.00	—	Mo 0.75 max.
440B	0.75-0.95	1.00	1.00	0.040	0.030	16.00-18.00	—	Mo 0.75 max.
440C	0.95-1.20	1.00	1.00	0.040	0.030	16.00-18.00	—	Mo 0.75 max.
446	0.35 max.	1.50	1.00	0.040	0.030	23.00-27.00	—	N_2 0.25 max.
501	Over 0.10	1.00	1.00	0.040	0.030	4.00-6.00	—	—
502	0.10 max.	1.00	1.00	0.040	0.030	4.00-6.00	—	—

These revised compositions were approved by the American Iron & Steel Institute April 16, 1947

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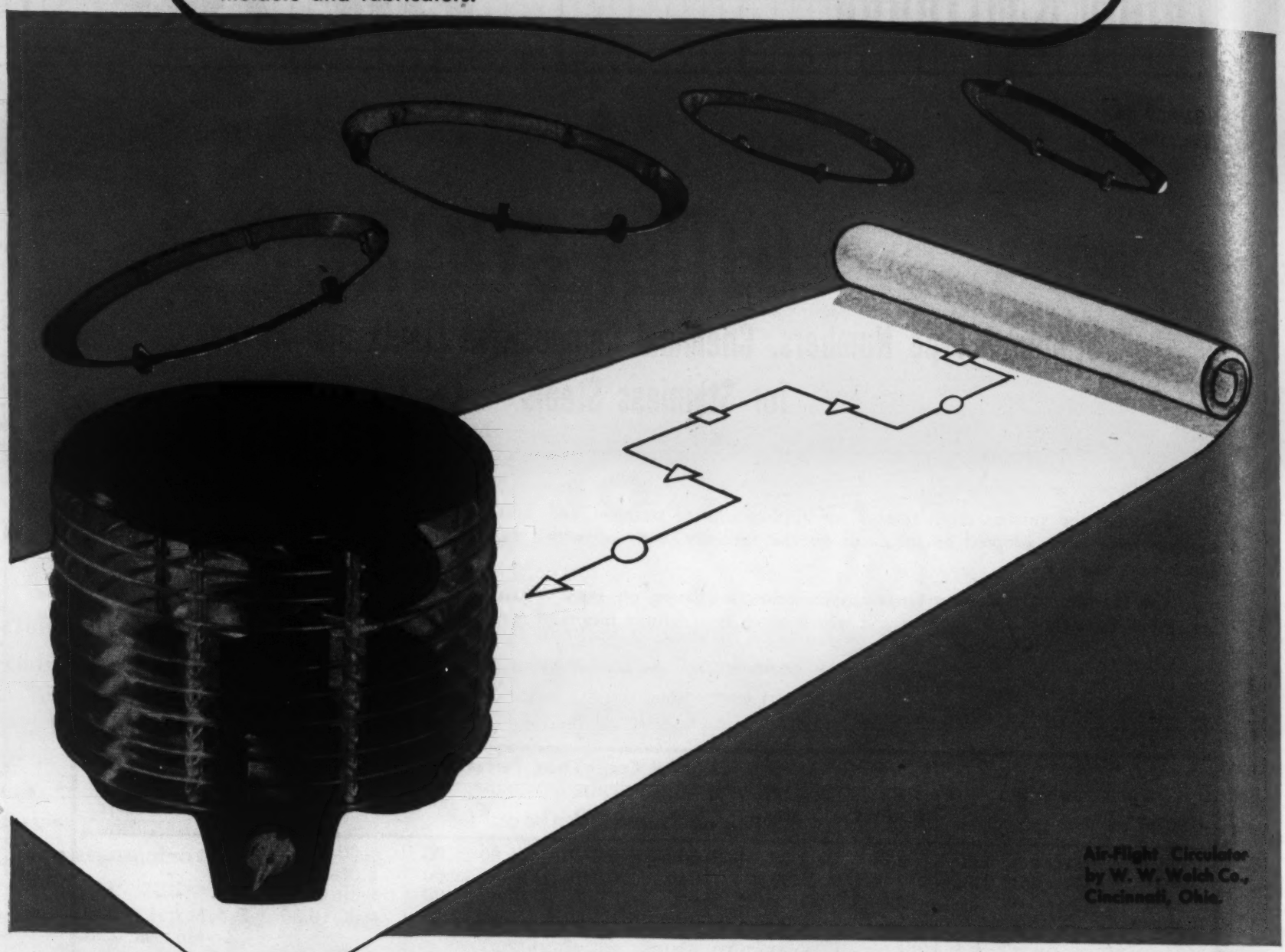

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MATERIALS & METHODS Engineering File Facts

NUMBER 143
June, 1947

METHODS: Forgings

Tolerances for Impression Die Forgings

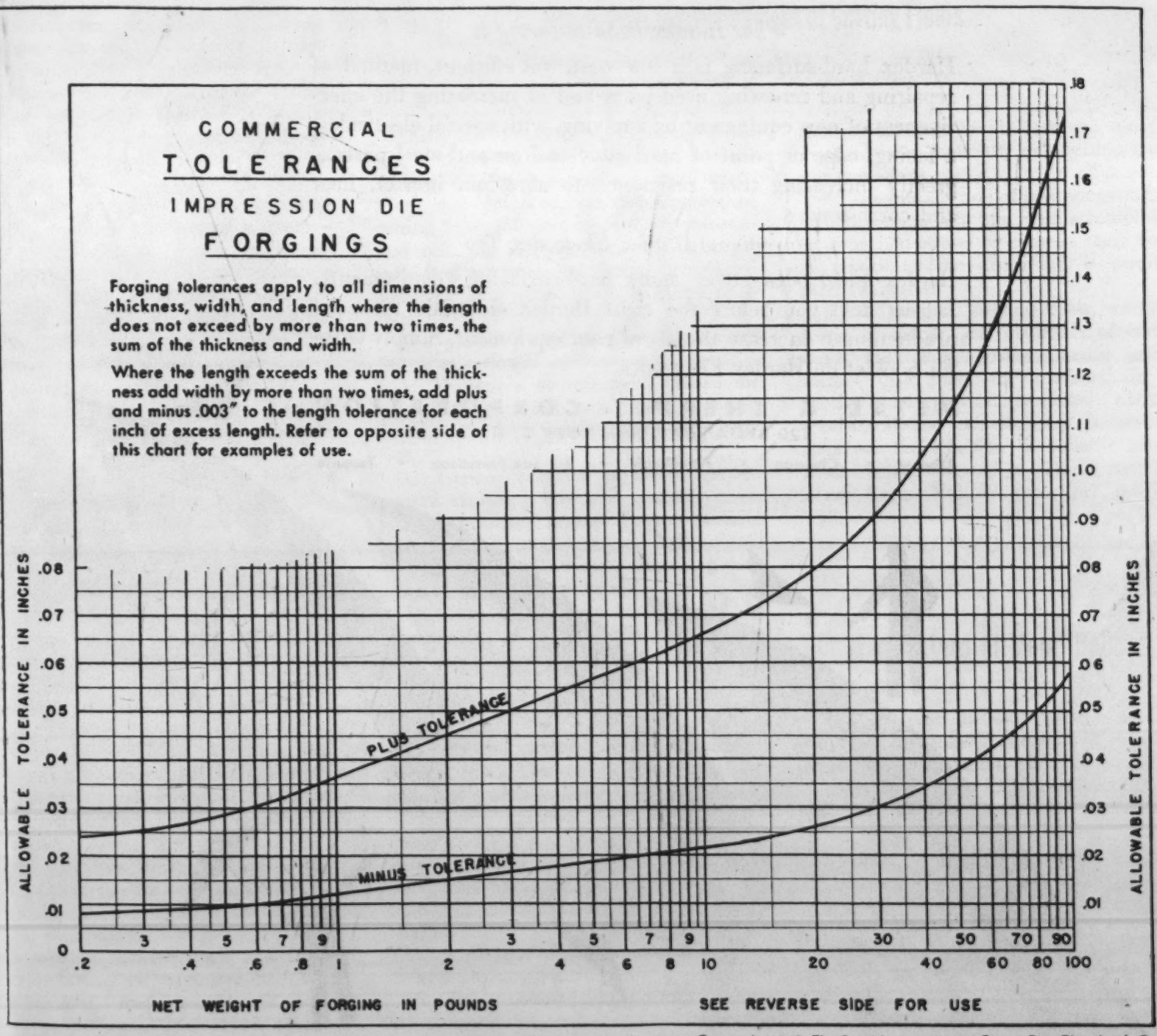
How to Use Tolerance Chart

Example

A cylinder forging is 2 in. dia. by 6 in. long and weighs 5 lb. The width and thickness tolerances at 5 lb. on the chart are plus 0.057 and minus 0.019, or, in nearest fractional dimensions, the width and thickness tolerances are plus 1/16 in. minus 1/64 in. Since the length of 6 in. is less than two times the sum of width and thickness (2 in. + 2 in.) x 2 = 8 in., as explained on the face of the chart, plus 1/16 in. minus 1/64 in. apply for all the dimensions.

Example

A forging is 1 in. thick by 3 in. wide and 14 in. long and weighs 12 lb. From the chart, the width and thickness tolerances are plus 0.069 and minus 0.023. Twice the sum of the width and thickness is (1 in. + 3 in.) x 2 = 8 in. Excess length = 6 in. 6 x 0.003 = 0.018. Adding 0.018 to 0.069 = + 0.087. Adding −0.018 to −0.023 = −0.41. The length tolerance is plus 0.087 minus 0.041. In nearest fractions, the width and thickness tolerances are plus 1/16 in. minus 1/32 in., and length tolerances are plus 3/32 in. minus 3/64 in.



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MATERIALS & METHODS DIGEST

A selective condensation of articles — presenting new developments and ideas in materials and their processing — from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Controlled Atmospheres of City Gas for Heat Treating Steel

Condensed from a Paper of the American Institute of Mining and Metallurgical Engineers

The use of city gas for controlled atmospheres in the heat-treatment of steels has the advantage of being comparatively cheap and "on tap" in most, if not all, industrial centers. The use of raw city gas itself as a protective atmosphere is not satisfactory because of its complex composition and its explosive nature when mixed with air.

It is, however, practicable to use an atmosphere obtained by burning city gas with a volume of air less than that required for complete combustion. With the proper design of combustion chamber it is possible to obtain a nonexplosive atmosphere and still retain some of the original reducing gases.

The bright annealing of low-carbon steel in such a complex atmosphere involves a careful consideration of the physical chemistry of gas-metal reactions to avoid oxidation of the iron. High-carbon steels present the problem of reactivity of the carbon with the atmosphere. It is important, therefore, that the factors influencing the composition of the generated gas be fully appreciated.

The design of the combustion chamber is important and should be such that the recommended temperature conditions are obtained within the rated capacity of the generator. A minimum contact time of 5 sec. between the gases and the combustion chamber is recommended.

Partially burnt city gas is suitable, as generated, for the bright annealing of medium and high carbon steels only at temperatures below around 1250 F. At higher temperatures the concentrations of carbon dioxide and water vapor lead to excessive decarburization. The complete removal of both these gases leaves an atmosphere that is carburizing to carbon steels at temperatures above 1400 F. The carburizing power, however, can be neutralized by a controlled concentration of either of the gases.

Burnt city gas does not descale hot-rolled strip as rapidly as a burnt ammonia atmosphere of the composition normally used for this purpose, excepting the atmospheres so rich in hydrogen and carbon monoxide as to be explosive and toxic. (Ivor Jenkins. Paper, *Am. Inst. Mining & Metallurgical Engrs.*, Mar. 1947 Meeting, 58 pp.)

Trends in Development of Cutting Fluids

Condensed from "Transactions of the American Society of Mechanical Engineers"

Thirty or 40 years ago cutting fluids commonly used were lard oil, straight mineral oil, soda water, and soap water. From that point on the development of cutting fluids followed through the mineral-lard oils, the sulfurized mineral oils, the sulfurized fat bases, the various chlorinated additives, and recently, the synthetic additives.

The present trends may be summarized briefly as follows:

1. There is a distinct trend toward the use of light-colored, transparent, odorless cutting oils; both corrosive and noncorrosive.

2. Greater attention is being directed toward exploring new and synthetic materials that impart greater extreme-pressure and oiliness properties to light-colored odorless cutting oils without impairing their color or odor characteristics.

3. There is a definite trend toward the greater use of soluble oils and soluble compounds, especially in machining operations.

4. Builders of machine tools are beginning to recognize the importance of sealing effectively the cutting-fluid and lubrication systems of machine tools so that soluble oils and compounds can be used for cutting operations if desired.

5. There is a growing tendency on the part of users of cutting fluids to ask for a noncorrosive cutting oil in both cutting-fluid and lubrication systems, especially in automatics where leakage is encountered. Builders in general, however, seem reluctant to approve this practice.

6. The maintenance of uniform cutting-oil temperatures by means of refrigeration equipment is receiving considerable attention on the part of builders and users of machine tools, especially in precision-grinding operations.

7. The introduction of new nonpetroleum soluble compounds has been accomplished by concerted efforts to evaluate their range of service and to determine, if possible, their limitations.

8. Builders of machine tools, manufacturers of metals, and marketers of cutting fluids are taking greater interest in the factors that affect the machinability of metals, and particularly those physical, mechanical and metallurgical factors that influence the selection of suitable cutting fluids. (J. T. Beard, Jr. *Trans. Am. Soc. Mech. Engrs.*, Vol. 69, Feb. 1947, pp. 131-138.)

Manufacture of Metal Bellows

Condensed from "Metal Industry"

In the past, bellows were formed by spinning or rolling. Recently a hydraulic method of formation has been introduced (trade name in the U.S.A.—Hydron). This method involves unrestricted flowing of a thin walled metal tube (the wall thickness of which is seldom over 0.005 in.) in a collapsible die. The metal flows transversely between the plates of the die under an internal pressure, the tube being collapsed endwise as the pressure is applied. The bellows are formed in a continuous operation.

Since any tube with a hidden flaw will burst under the high internal pressure, the

DIGEST

process is "self-inspecting." The hydraulic method of cold working gives uniform properties and wall thickness with no uneven stress distribution. The physical properties of finished bellows are determined by the grain size and amount of cold working.

In the design of metal bellows two main properties must be kept in mind: that of a spring to withstand repeated flexing and that of a container which may be hermetically sealed. Metal bellows are applicable to gland seals for rotating shafts or to the glands of shafts having a reciprocating motion. They are also used successfully for transmitting movement by hydraulically filled vessels.

Larger bellows provide reservoir chambers capable of taking overflow liquid from a main chamber as a result of expansion, the complete unit being hermetically sealed. The metal bellows can also be used to great advantage in temperature regulation by remote control. (*Metal Ind.*, Vol. 70, Jan. 24, 1947, pp. 69-70.)

Development and Applications of Lime-Ferritic Electrodes

Condensed from "The Welding Journal"

The ultimate development of an electrode possessing the performance characteristics imparted by the lime-ferritic coating has been considered inevitable for some time. The advantages which lime-ferritic electrodes have over conventional electrodes may be summarized as follows:

1. They have the ability to weld different varieties of plain carbon steel, such as rimmed and killed steels, without a variable degree of reaction pitting and X-ray porosity.

2. They allow the introduction of reducing type of alloy additions, such as silicon, manganese, chromium and vanadium, without noticeably upsetting performance characteristics.

3. They can be used to weld free machining steels without surface and X-ray porosity and weld cracking.

4. They have the ability to weld drastically air hardening steels without the formation of underbead cracking.

However, certain shortcomings have necessitated the use of a modified technique which has slowed field acceptance. The favorable impact properties at low temperatures possessed by this electrode, together with its ability to satisfactorily weld steels heretofore considered unweldable, has established for this type a unique position in the welding industry as one of the most universal electrodes available today. For example, high sulfur steels, air-hardening steels, and complex alloy steels are readily welded with this electrode.

In spite of the advantages cited, the lime-ferritic electrode is not intended to be a panacea for every welding problem. Its development, nevertheless, is a step in reaching the ultimate objective: To produce an electrode capable of welding a variety of steels under highly diversified conditions.

This report compares the low-temperature impact properties of the unalloyed lime-ferritic weld deposit with the conventional heavy coated E-6020 weld deposit in the temperature range 70 F to –112 F and shows that a change in type of fracture occurs at approximately –22 F for the lime-ferritic deposit. (D. L. Mathias & A. P. Bunk. *Welding J.*, Vol. 26, Mar. 1947, pp. 209-217.)

Hot-Shortness in Welds and Castings of the Aluminum-Silicon Alloys

Condensed from "Journal of the Institute of Metals"

The hot shortness of a series of alloys was studied by means of casting and welding experiments. The alloys comprised 99.5% aluminum and eight commercially pure aluminum-silicon alloys with 0.25 to 12% silicon.

In the casting tests, four to 14 ring castings were made of each alloy in an open mold. The severity of cracking was expressed numerically as the total length of cracks on all surfaces with no weight given to the width or depth of the cracks. The severity of cracking increased sharply with the addition of silicon to a maximum at 0.7% and then decreased less rapidly, reaching zero at about 3% silicon.

In the welding tests, sheets were bolted in a jig and welded with a neutral oxy-acetylene flame using a filler rod cut from the parent sheet. From two to four welds were made on each alloy. The amount of cracking was expressed as the total length of cracks on both sides of the sheet. The results were remarkably similar to those obtained in the casting experiments; the cracking reached a maximum at 0.8% silicon and decreased on either side. In both cases, the cracking occurred above 930 F.

The hot cracking of castings and welds can be accounted for theoretically by one principal factor, the extent of the hot-short temperature range, which is greatest at the composition coinciding with the limit of solid solubility. Castings and welds made in alloys within the hot-short composition range are subject to cracking during solidification if free contraction is prevented. The greatest degree of hot shortness occurred in alloys with 0.7 to 0.8% silicon; this probably coincides with the effective solid solubility limit under the test conditions where equilibrium was not attained. The compositions of the most common aluminum-silicon alloys lie beyond this range, but an undue amount of silicon in commercial aluminum makes it hot short and may cause much trouble during welding. (A.R.E. Singer & P. H. Jennings. *J. Inst. Metals*, Vol. 73, 1946, Part 4.)

Sub-Zero Treatment of Steels

Condensed from "The Engineers' Digest"

Beneficial effects can often be realized from sub-zero treatment of steels. The temperatures involved in these treatments are usually –90 to –120 F. There are two main classes of treatment. One uses low temperatures as a part of the heat treatment of high-speed steels, to give longer tool life. The other use is in the treatment cycle of highly alloyed steels. In this case treatment is advantageous from the point of view of increased dimensional stability and hardness. Both uses aim at the complete removal of the objectionable austenite which often remains after normal heat treatment.

Reports on actual application of sub-zero treatment to high-speed tools are very conflicting. Some users claim improvements of literally hundreds of per cent increase in the number of components per regrind per tool. From the author's work, observed improvement was in the 10% region.

Generally speaking, far too little practical application of sub-zero treatment has been applied to determine accurately the improvement to be expected treating high-speed steel.

Sub-zero treatments have a definite place in the thermal treatment of other highly alloyed steels. Many of these steels are commonly used for highly stressed components manufactured to close tolerances, or for dies and press tools, again held to close dimensions. Austenite, therefore, is undesirable because optimum hardness is not obtained, there is danger of dimensional instability, there are thermal stresses, and the possible effect on the surface finish during finishing operations.

There are many aspects of the use of low temperatures that still need to be investigated. Observations such as those concerning the softening effect of various tempering temperatures on steels heat-treated with and without sub-zero treatments require further study. (G. H. Jackson. *Engineers' Digest* [Am.], Vol. 4, Mar. 1947, pp. 104-108.)

German Light Metals Industry

Condensed from a Report of the Office of Technical Services

A 30,000-ton forging press was used at I. G. Farben during the war for forming light metal shapes. The large capacity and die space of the press made it possible to forge brackets about 10 ft. long and aircraft wheels more than 36 in. in dia. About 75% of the engine mounts and all the wheels were made of magnesium alloy.

Only two operations were required to make an aircraft wheel—one to flatten the blank and another to forge the wheel. Complex magnesium forgings, such as supercharger rotors, were made requiring a minimum of machine finishing. Experimental attempts to forge very long pieces had not succeeded up to the war's end. No work approaching the machine's theoretical capacity had been attempted.

The 30,000-ton press, put into opera-

tion in Oct. 1943, was twice the size of any die forging press then in use and is still the world's largest. The press approximates a double 15,000-ton press. Its total height is 80 ft., of which 27 ft. is below floor level. The press has eight columns, 31 in. in dia., and eight cylinders, 41 in. in dia. with a 70-in. stroke. The ram and bed dimensions are 33 by 11 ft., with a die opening (bed to ram, stroke up) of 9 ft. The die shifting carriage has a 25-ft. stroke.

In addition to the use of unusually large forging and extruding presses, the investigators found German refinements in the reduction of aluminum and magnesium scrap. The investigators considered the magnesium casting shop and scrap recovery plant at Strassfurt the most efficient and best laid out plant of its kind. Located on the lower of two floors were the furnace pits, exhaust flues, gas and air lines, pouring station, elevating equipment, ingot saws and scalpers, and ingot storage space. The upper floor was kept clear for pouring and for full use of overhead cranes.

The German process for recovery of aluminum and magnesium from mixed alloy scraps was also unique. In the process molten alloys of both metals are refined or more literally "washed" with an excess of molten magnesium. The refined metals are pure enough for commercial light alloy production. Molten magnesium is added to a charge of crudely separated, melted scrap alloys.

Interaction of the molten magnesium and melted scrap results in the formation of insoluble intermetallic compounds of aluminum and magnesium with iron, manganese, silicon, chromium, vanadium, molybdenum, titanium, zirconium and cerium. The magnesium and aluminum compounds are filtered out as crystals when the temperature of the melt nears the solidifying point.

The remainder of the mixture is heated in a hydrogen atmosphere at extremely low pressure (2 mm. of mercury) in a closed furnace. The magnesium and other metals are distilled out, leaving a residue of aluminum and small amounts of copper, nickel and tin. These impurities are not considered undesirable because the demand for copper-bearing duralumin alloys is enough to absorb the entire product of the process. (Herbert H. Hall & James T. Kemp. Paper, *Office Tech. Services,* 528 pp.)

The Fabrication of Parts in Cast Steel Designed for Aircraft Construction

Condensed from "Fonderie"

Although long used sparingly and with great caution in airplanes, steel castings are now being employed in vital parts. Much patient development was necessary to produce steel castings of the degree of perfection required for such parts. Modern methods of non-destructive inspection have done much to improve foundry technique. During the war, the English and Americans started to utilize steel castings in their airplanes.

The Germans were the first to use steel castings for important operating parts. In spite of their slowness in getting into operation, the difficulties of casting, the lightness of the parts, the severity of inspection and the size of the rejections, the production of steel castings for the Luftwaffe during the course of the war represented a sizable tonnage.

In peace time, it is important to examine the role of the builder and of the foundryman in the design and execution of parts. The builders must simplify their designs to reduce delays, to accelerate production, and to decrease the number of rejections. Cooperation between builders and foundrymen is indispensable. A design should not be considered as final until it has been approved by experts in charge of each of the phases of its manufacture.

No problem is insolvable if all are willing to make reciprocal concessions and a common effort to obtain a product that will have the reliability, lightness and strength required for aircraft work. It is important to allow the foundry sufficient time for tooling-up. It is foolish for the builders to choose a foundry solely on the basis of a quick delivery promise. Other criteria, such as previous experience and competence, are also factors.

The fear of competition has been overcome by large scale cooperation among the foundries designed to further the use of castings. Foundries specializing in the casting of aircraft parts must have adequate laboratories. Foundries must also attempt to improve and perfect their methods and periodically review their practices to maintain an up-to-date technique. (R. Buquet. *Fonderie,* Vol. 11, Dec. 1946, pp. 397-415.)

An Improved Slow Aging Duraluminum for Rivets

Condensed from "Revue de l'Aluminium"

Riveting is the most commonly used assembly means in aircraft construction. Standard duraluminum rivets are in the best condition for riveting when they are freshly quenched. Because of the rapidity of aging, they must be used within 2 to 2½ hr. after quenching. While refrigeration delays aging, not many shops in France have suitable equipment.

A homogenization treatment during the bar or billet stage does not delay the aging of duraluminum. The upsetting properties as quenched are improved by this treatment, however, so the time interval within which satisfactory riveting may be done is extended to about 4 hr.

To develop slow aging alloys, tests were made on a series of 27 alloys with 2, 3 and 4% copper, 0.3, 0.6 and 1.2% magnesium and 0.15, 0.3 and 0.6% silicon. A simple cold upsetting test was used in this investigation along with the requisite shear and tensile tests. Low copper, magnesium and silicon contents were found desirable for good upsetting properties and slow aging characteristics. An alloy with about 2 copper, 0.6 magnesium and 0.15% silicon was considered the most interesting (it will be noted that this is similar to A17ST used in the U.S.A.). This alloy not only ages very slowly but even when completely aged has cold upsetting properties superior to those of freshly quenched duraluminum. As aged, this alloy has a tensile strength of 46,940 psi., a 0.2% elastic limit of 23,450 psi., an elongation of 20.2%, and a shear strength of 29,870 psi.

The upsetting test used in this investigation is believed to offer advantages as a control test for wire to be used for rivets. It gives an easily interpreted result and likewise shows up defects in the wire itself. (Y. Bresson. *Rev. l'Aluminium,* Vol. 23, Dec. 1946, pp. 384-390.)

Developments in the Application of Aluminum Alloys

Condensed from "Metallurgia"

The development of the uses of aluminum is phenomenal. Shortage of other materials is one factor but there are others, such as price, that are more enduring.

Although aluminum probably will not be used in the construction of houses to any great extent in the future, the all-aluminum house will undoubtedly leave its mark by extending the use of aluminum for windows, partitions, fittings and furniture. Its employment in the main structure of buildings will be economically justified only to meet special requirements. More ordinary examples include excavator booms and buckets, cranes and mechanical shovels, for all of which important advantages accrue from the use of lighter materials. An interesting development is the use of aluminum for scaffold structures.

There seems little doubt that the eventual result of work by the manufacturers of motor car bodies will be the large scale adoption of aluminum for body components, such as doors, and even complete bodies. Little progress has been made in arousing the active interest of railway engineers although aluminum is being used to equip and decorate special trains. Large numbers of small boats are being built of aluminum and some progress in the main stream of shipbuilding is evident, such as the construction of light alloy superstructures.

Aluminum bins for refuse have now been adopted. Many colliery firms are showing interest in aluminum for portable equipment. Aluminum is being considered for printing furniture because of its lightness.

The drastic change in the relative prices of aluminum and copper is engaging the attention of electrical manufacturers. There are still problems of joining aluminum conductors for insulated cables. Lightness and ease of manipulation are the advantages offered by aluminum in electrical

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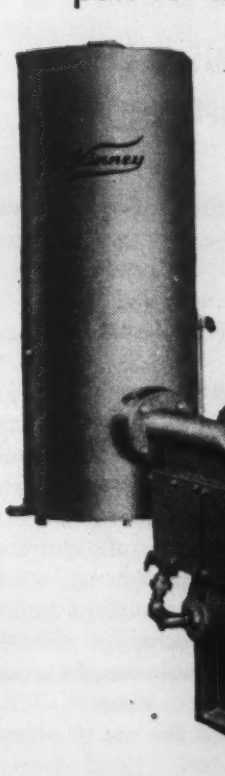
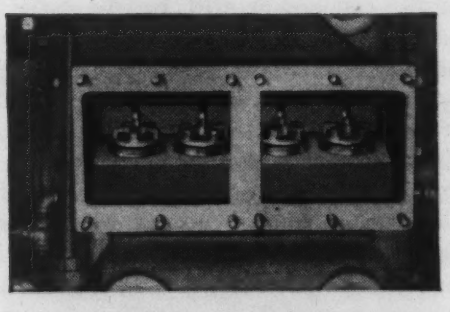


KINNEY Single Stage Vacuum Pump

1 KINNEY design reduces wear. The rotating plungers in the KINNEY Pump have no mechanical contact with the cylinder surfaces, all clearances being perfectly sealed and lubricated by oil under pressure. The pump has no internal packings, piston rings or valve gear. Low absolute pressures are produced indefinitely — down to 10 microns with the Single Stage Pump and 0.5 micron with the Compound Pump.

2 High quality materials and accessories assure trouble-free operation. The installation of Durabla Discharge Valves of Monel metal . . . the leakproof valves that are famous for their high efficiency . . . is typical of the careful engineering to provide years of service and easy repair. The cast parts of these valves, as well as the castings for the pumps themselves, are of an alloy which is exceptionally dense and strong.



Durabla Valve Units as installed in KINNEY Vacuum Pump

The extremely dependable performance of KINNEY High Vacuum Pumps, combined with their fast pumping speed and low ultimate pressures, make them ideal not only for exhausting lamps and tubes, but for sintering alloy metals, coating lenses, producing penicillin and aiding in scores of process operations.

Write for Bulletin V45.

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conduit tubing. Another promising field is the replacement of lead in sheathing cables.

Aluminum milk cans and churns should be a permanent application provided the cost, as compared with tinned steel, can be reduced. Another instance in which shortage of standard materials creates an opportunity for the introduction of aluminum on a permanent basis is that of beer barrels. (E. D. Illiff. *Metallurgia,* Vol. 35, Feb. 1947, pp. 197-201.)

Welded Bases for Metal Processing Equipment

Condensed from "Machines et Métaux"

Traditionally, the bases of machine tools and of many engines are gray iron. This material has advantages of good casting properties, low cost, easy machinability and good abrasion resistance. Advocates of welded mild steel, on the other hand, emphasize its robustness, safety, homogeneity and versatility. Also, if only a few bases are involved, the cost per piece by casting will be higher. For equivalent shape and equal strength, the weight of a welded steel base will be about 40% that of cast iron; for equal rigidity, about 60 to 70%.

The three main objections to a welded steel base for machine tools are its low damping capacity, inadequate dimensional stability, and inferior abrasion resistance as compared with cast iron. However, the vibration amplitude of a welded steel base weighing 30 to 40% less than a cast iron base will be less than that of the cast iron base as a result of the higher modulus of elasticity of the steel. Dimensional stability is readily attained by a suitable stress relief. As far as abrasion is concerned, the parts involved can be made of a medium carbon steel and superficially hardened after welding.

In presses and hammers, where very high stresses are involved, there has been increased development of welded steel bases to get desired lightness and safety. Welding is almost universally used for housings. Welded assemblies of castings and wrought steel make possible the use of simple castings for large sections and wrought steel for the balance. It is essential that designers realize the possibilities and limitations of pre-machining prior to welding.

The tonnage of welded construction is less in France than in the U.S.A., although all types of welded bases have been manufactured in France. Welded bases are not more widely used in France because of the conventional use of castings and lack of information in the shops on welding pro-

cedure and weldable materials. (H. Gerbeaux *Machines et Métaux,* Vol. 31, Jan. 1947, pp. 3-7.)

Status of Bearing Lining Materials

Condensed from a Paper of the Society of Automotive Engineers

In the manufacture of bearings, several metals considered as raw materials are essential. The present status in obtaining these is not good. Tin and antimony are still under direct government control. Cadmium, used in the manufacture of cadmium-silver-copper alloy bearings, is exceedingly tight owing to the fact that the demand actually exceeds the supply. Steel, the backbone of the bearing industry, is difficult to obtain owing to the urgent demand placed upon fabricators. Lead and copper are still very hard to obtain. Silver, nickel and zinc, of secondary importance only in the manufacture of bearings, are all available; and aluminum, although difficult to obtain in some forms, can be had.

There are two general methods of producing bearings. The most popular is by means of lining steel tubes or bronze full round castings with the desired lining alloy, known as the tubing method. The other is the strip process in which a long steel strip approximately 6 in. wide is moved continuously through a mill which applies the lining material to the steel.

A listing was compiled by consulting four bearing production experts to indicate the approximate 1947 output of bearing in the United States. The basis for these percentages is bearing pieces used in reciprocating machines, engines or compressors, expressed in a percent of the total.

Production of Sleeve Bearings by Materials

	Tubing	Strip
Tin-base babbits	5%	10%
High lead babbitts	6%	54%
Cadmium alloys	4%	2%
Copper alloys	1%	4%
Copper alloys — overplated	2%	10%
Aluminum alloys	1%	1%
Silver	—	—
Silver — overplated	Negligible	Negligible

It is predicted that in the future copper and aluminum alloys will become more popular, with the production of high lead babbitt bearings dropping. A slight increase in the use of tin-base babbitts is also

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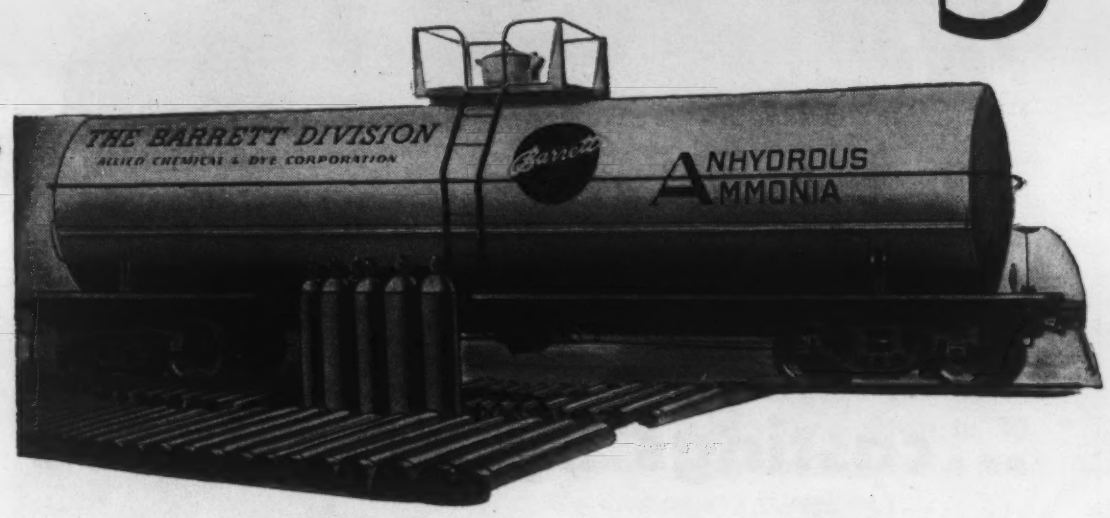

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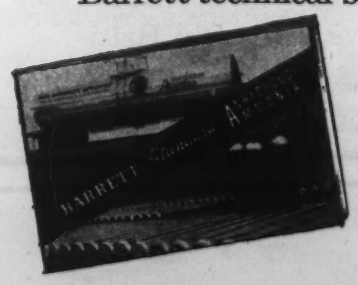

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DIGEST

predicted. The use of lead-tin plating the internal surface of some copper alloy bearings will be responsible for some of the increase in the use of this alloy, since this permits the material to be run with normal untreated crankshafts. (W. E. Thill. Paper, *Soc. Automotive Engrs.*, 7 pp.)

The Role of Surface Condition in the Measurement of Hardness

Condensed from "Revue de Metallurgie"

In the measurement of hardness with low loads, the operator may want either to measure the characteristic hardness of the metal independently of the surface or to investigate the physical and chemical surface condition.

The Herbert pendulum test gives precise results independent of the surface condition if the test is made on a metal sufficiently soft so that the surface irregularities are effaced by the movement of the pendulum. Although the test is very superficial, the standard deviation is small (of the order of 1 to 3%). The Vickers test will also give results independent of the surface if the size of the impression (and, therefore, the load) is suitably adjusted to compensate for the surface irregularities. The measurement of the depth of penetration (for example, with the Microdurometer E.P. using a Rockwell diamond) is inadvisable if the tests are made on a hard or unpolished metal, particularly when the initial load is low.

The Herbert pendulum test is suitable for investigating slight physical and chemical modifications of the surface, such as decarburized or nitrided layers. Here, too, the standard deviation is about 1 to 3%. If the pendulum test is used on metal with systematic surface irregularities, the results are a function of these irregularities if the metal is hard enough so that the irregularities are not effaced by the pendulum.

To keep the standard deviation within acceptable limits, the oscillation of the pendulum should be parallel to the ridges on the surface. In studies on low carbon steel sheet, it was found that there was a significant difference in the Herbert hardness, depending upon whether the oscillation was parallel or perpendicular to the direction of rolling. This difference is not due to surface anisotropism but is an interesting result of the crystal mass, as it was found to the same degree on highly polished surfaces and at the midsection of the sheet. (P. Bastien & A. Popoff. *Rev. de Metallurgie*, Vol. 42, Dec. 1945, pp. 373-388.)

Tungsten

TUNGSTEN—SECOND EDITION. *By K. C. Li & C. Y. Wang. Published by Reinhold Publishing Corp., New York 18, 1947. Cloth, 6¼ x 9¼ in., 435 pages. Price $8.50.* This revised edition is a considerable expansion of most of the chapters of the first edition. Aside from this it departs very little from the structure of the former text. Up-to-date material has been included, particularly in the chapters on "The Geology of Tungsten" and on "The Industrial Application of Tungsten." Much of this was suggested by reviewers and metallurgical readers.

This new edition will be regarded as the most detailed and authoritative work in this field thus far to be published. Practically every possible phase of the metal has been covered. The illustrations, some in color, which were a marked feature of the first edition, have been all retained. The volume is Monograph No. 94 in the series of the American Chemical Society.

The scope of the work can be judged by the titles of the nine chapters which are as follows: "The History of Tungsten," "The Geology of Tungsten," "The Ore Dressing of Tungsten," "The Metallurgy of Tungsten," "The Chemistry of Tungsten," "Analysis of Tungsten," "The Industrial Application of Tungsten," "Substitution of Tungsten," and "The Economics of Tungsten."

There are four appendices: "Terms of Purchase of Tungsten Ores," "Chinese Contracts," "Post-War Tungsten Situation," and "References Relating to Tungsten Alloys."

Machine Design

MACHINE DESIGN — FIFTH EDITION. *By L. J. Bradford & P. B. Eaton. Published by John Wiley & Sons, Inc., New York, 1947. Cloth, 5¾ x 8½ in., 283 pages. Price $3.25.* The authors, in preparing this new edition, have adhered strictly to the objectives announced in the first edition—it is presented solely as a textbook, and is intended for use in courses in machine design where time is limited and a more extensive text would be cumbersome.

This fifth edition has been thoroughly brought up-to-date. Progress made in the field during the past six years or so has been reviewed and incorporated, and all obsolete material has been deleted.

Additions which have been made deal

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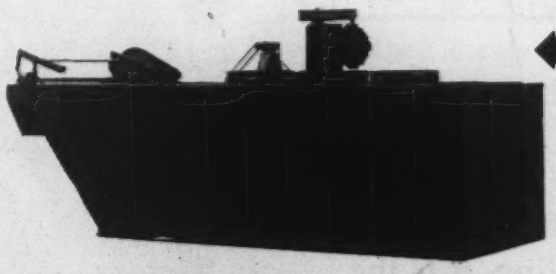

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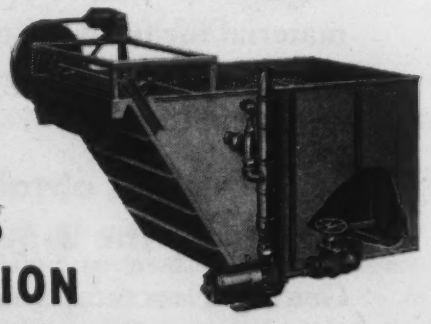

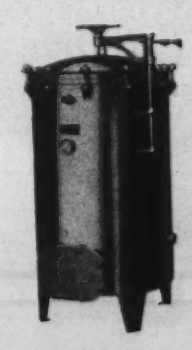

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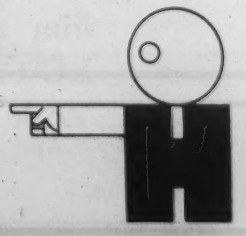

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primarily with the fatigue of metals, with current theories on the nature of friction and lubrication, and with special precautions necessary in designing parts made of aluminum, a metal made more important by its extensive use in the war.

The present scope of the textbook is revealed by the following chapter headings: Fundamental Definitions and Considerations; Friction and Lubrication; Bearings and Sliding Surfaces; Friction Clutches and Brakes; Shafts; Force and Shrink Fits; Screws and Screw Fastenings; Toothed Gearing; Belts and Chains; Springs; Flywheels; and Miscellaneous Machine Elements.

Injection Molding of Plastics

INJECTION MOLDING OF PLASTICS. *By Islyn Thomas. Published by Reinhold Publishing Corp., New York 18, 1947. Cloth, 6¼ x 9¼ in., 545 pages. Price $10.00.* This book is written for the plant engineer, the product and mold designer, the shop foreman, and the plastics technologist. Its timeliness is obvious. The increase in the number of injection machines in the United States—from about 1,000 in 1940 to approximately 3,450 at the end of 1946—is a measure of the value of injection molding to the plastics industry.

The history and development of injection molding from its inception to the present time are discussed, and the features of the important machines and their operation are treated in detail. The fact that there are 445 illustrations and five color plates reveals the broad scope of the work. Most of these deal with mechanical details and operating technique.

An introduction to the book has been supplied by Mr. Charles A. Breskin, editor and publisher of *Modern Plastics*. In this he says that "for those who want to be up-to-date on the injection molding of plastics and the plastics industry, a comprehensive book on injection molding is long overdue. Mr. Thomas' book is the first of its kind. . . . The book is at once a text in its factual sequence, a handbook in its wealth of technical data, and a complete survey of plastics and injection molding that is simple enough for the layman to follow."

There are eight chapters and two appendices. Titles of the chapters are: History, Development of Injection Molding Techniques, Materials for Injection Molding, Molding Practices, Product Design, Mold Design and Construction, Finishing and Decorating, and Estimating the Costs.

The author is president of the Thomas Engineering Corp., Newark, N. J. He is an engineer of ability and broad experience.

Fibers and Textiles

THE NEW FIBERS. *By Joseph V. Sherman & Signe L. Sherman. Published by D. Van Nostrand Co., Inc., New York, 1946. Cloth, 6 x 9 in., 537 pages. Price $5.00.* This book is described as the first one

that tells the complete story of all the new developments in fibers and textiles, many of them of importance in industrial products.

There is included a general discussion of new fibers and a comparison of their properties with those of the older established fibers. Each of the important new fibers is discussed in separate chapters, and there is a summary of the history and development, manufacture, chemical and physical properties, established and potential applications, and available data on volume of production and prices. There is also a broad discussion of trends in research and development work for both the manufactured and natural fibers with an appraisal of the competitive positions.

A feature of the volume is an appendix containing a classified list of about 1600 U. S. patents taken out in the last 10 years.

There are 19 chapters listed as follows which gives an idea of the scope of the work: Introduction; Comparison of Fibers; Nylon; Vinyl Resin Fibers; Vinylidene Chloride Fibers; Glass Fibers; Polyethylene Fibers; Other Synthetic Fibers; Casein Fiber; Soybean Protein Fiber; Other Protein Fibers; Improved Rayons; Rayon Staple Fiber; Economic Aspects of Rayon; New Cellulosic Fibers; Miscellaneous New Fibers; Chemical Treatments of Textiles; and Applications and Trade Names. Each chapter has a list of references, and there are about 80 illustrations.

The book will be highly appreciated by those interested in all phases of fibers and their use.

Other New Books

MANUAL OF DESIGN FOR ARC WELDED STEEL STRUCTURES. *By LaMotte Grover. Published by Air Reduction Sales Co., New York, 1946. 285 pages. Price $2.00.* Methods and procedures based chiefly upon the standards of the American Welding Society, the 1946 edition of the specifications of the American Institute of Steel Construction, and reports of the Welding Research Council's Structural Steel Committee. Includes a set of 26 diagrams for the rapid proportioning of the welded-groups and connections subjected to eccentric loading.

FACTS FOR FOUNDRYMEN—SIXTH EDITION. *By E. G. Jarvis & H. O. Jarvis. Published by Niagara Falls Smelting & Refining Corp., Buffalo 17, N. Y., 1946. Cloth, 4 x 7 in., 80 pages. Price $1.00.* Intended as a foundrymen's handbook, this booklet has been brought up-to-date in this, the sixth edition. Its revision has been stimulated by an ever increasing demand for information regarding the modern application of metals and alloys for specific purposes. Copper, lead, nickel, tin, zinc and their alloys as well as cast iron, Muntz metal, and malleable iron are among the topics covered.

SYMPOSIUM ON ATMOSPHERIC EXPOSURE TESTS ON NONFERROUS METALS. *Published by American Society for Testing Materials, Philadelphia 3, Pa., 1946. Cloth or heavy paper, 6 x 9 in., 145 pages. Price $2.25 (cloth) or $1.75 (paper); $1.70 and $1.35, respectively, to A.S.T.M. members.* Describes and evaluates a broad series of atmospheric exposure tests carried out over many years on nonferrous metals and alloys, a number of the tests having been underway over 10 yr.

ATOMIC THEORY FOR STUDENTS OF METALLURGY. *By William Hume-Rothery. Published by The Institute of Metals, London, 1946. Cloth, 5¾ x 8¾ in., 286 pages. Price 7s. 6d.* Prepared primarily to give advanced students and research workers in metallurgy an understanding of the ideas which underlie the new theories on the atomic structure of metals.

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Engineering Shop Notes

Projection Welding of Cabinet Latches Cuts Assembly Cost

by Wallace A. Stanley,
Progressive Welder Co.

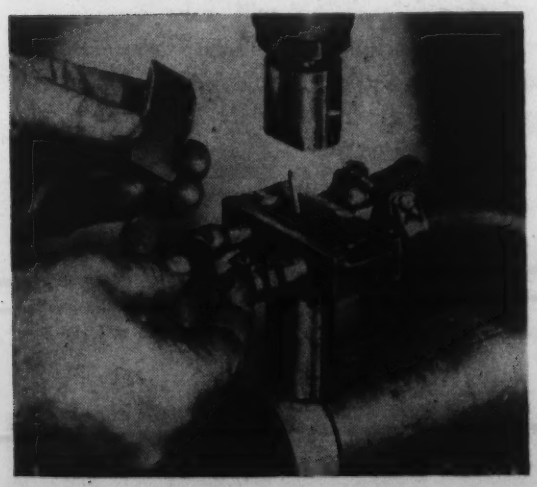
Projection welding coupled with a simple holding fixture has enabled Dedoes of Berkley, Mich., to not only reduce the time required to assemble its kitchen latches but also to cut assembly costs materially. The dies and machines were designed and produced by Progressive Welder Co. of Detroit.

The original design for flush latches for kitchen cabinet doors and drawers presented some difficulty in assembly. The stamped trigger cam has to be attached to the formed trigger plate at an acute compound angle. Moreover, the assembly method has to be such that no surface markings will be left on the front of the finger plate.

The part was originally assembled by silver brazing. This was rather slow and costly. The problem was finally solved with the design of a simple fixture (illustrated) for holding both parts in a standard projection welder. This made possible the joining of pieces by projection welding on a standard 50-Kva pedestal welder, while allowing rapid loading and unloading of parts without manual clamping or unclamping.

The upper die holds the trigger cam by automatic spring-clamping. The lower die has a plain recess for locating the finger plate. This permits straight line retraction of the welded assembly by the upper die, eliminating need for special collapsing dies.

The trigger cam, of course, was provided with two small projections. There is no marring of the finger plate. Production is 600 units per hr. Cost of joining parts is about one-quarter of the cost when using silver brazing.



This holding fixture permits rapid assembly of kitchen latches by projection welding.

Brush Plating for Small Jobs

by George Black

Beginning as a hobby a comparatively short time ago, electrolytic brush plating has come to be a handy industrial tool to a wide variety of industries. Briefly, modern brush plating units offer a means for applying decorative and protective metal coatings without the necessity for complicated equipment and control. The whole set-up is carried in a small case about the same size and weight of a portable typewriter, and since it operates at 110 to 120 v. a.c. (at 50 to 60 cycles), it is only necessary to plug it in the nearest socket.

Brush plating is not designed or intended as a substitute for still or barrel plating of production work. Its value lies in its portability and simplicity. It can be useful in the plating room for touch up work, but its main use is in the production line, where it can be used to touch up on assembly, saving the time of disassembly and transportation.

Advantages listed for this handy tool are: (1) low initial cost and low maintenance, (2) complete portability, (3) minimum of skill required, (4) saves time of disassembly, transportation, and (5) minimum of controls, equipment and space. Cadmium, chromium, nickel, zinc, copper, silver and gold are among the metals which can be deposited from prepared compounds.

Procedure for satisfactory electroplating by brush involves the following:

1. Clean and polish surface. The degree of polish before plating will determine the brilliance of the coating itself.
2. Rinse thoroughly. As in still or barrel plating, the surface must be chemically clean if good adhesion is to be obtained. Perfect cleaning operations are wasted if rinse methods are not carried out with sufficient care. Use clean water and cloths.
3. Plug in plating unit and regulate voltage in accordance with manufacturer's instructions. Plate slowly and carefully, a small area at a time. Make sure that correct anode is connected with brush. (Modern brushes come with removable anodes so that the same brush can be used for a variety of metals.)
4. Rinse thoroughly.

Among the types of organizations which have found electric brush plating profitable are garages, various manufacturing concerns, repair shops, electrical shops, radio shops, hotels and many others.

Heat Treating Fixture for Cyanide Bath

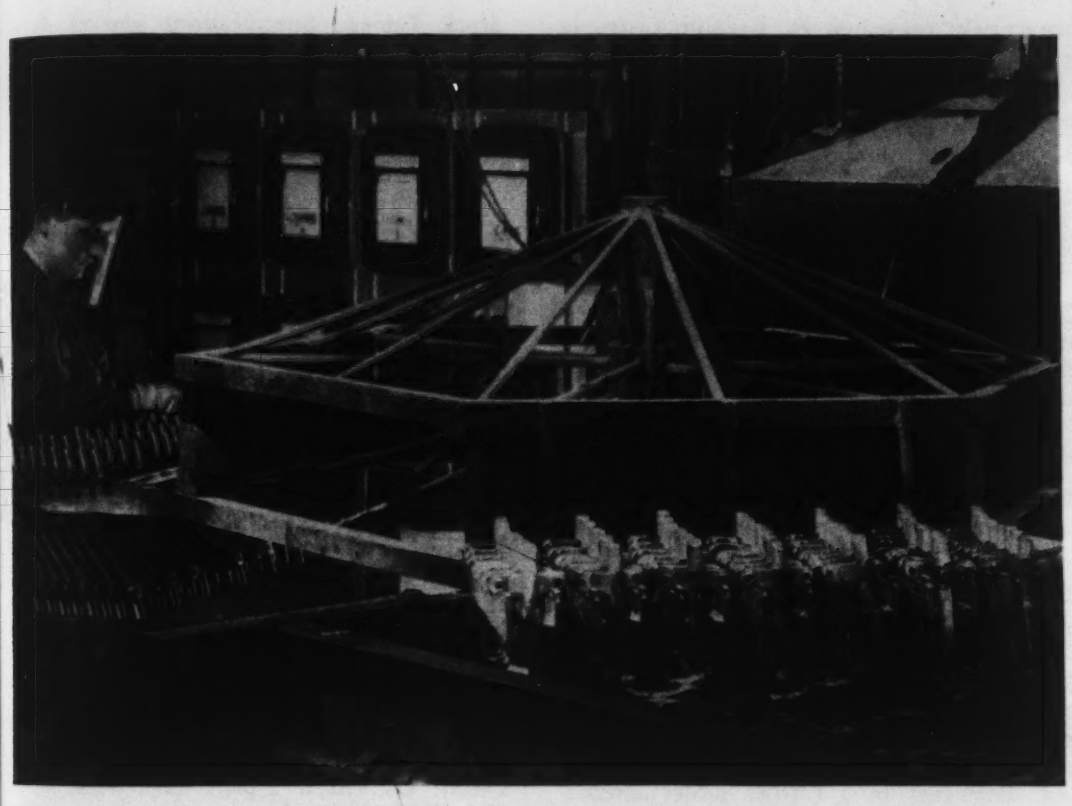
by C. E. Garwood,
Studebaker Corp.

Unable to get delivery on automatic cyanide heat treating equipment when it reconverted to automobiles, Studebaker built its own fixture.

The process employs a six-sided merry-go-round with space between three racks. As one rack is being loaded, parts in the second rack are subject to the cyanide bath while parts on a third are quenched in oil. Temperature lights warn the operator when to elevate the parts from the cyanide and index fixture.

Studebaker metallurgists favor the home-made fixture because they believe it more trouble-proof and obviously less expensive than an automatic system. The merry-go-round is moved vertically on a center post by a manually-controlled air cylinder. The operator can load and unload two of the fixtures, both of which use the same oil quench tank.

Advantages over the previous method of fork-loading the racks above the cyanide tanks are greater safety, decreased worker effort and increased productivity. Such parts as automobile steering knuckle support arms and clutch operating shafts are handled in less than half the former time.



One rack of parts being heat treated, while another rack is being loaded.

Plastic Blanket for Chromium Plating Baths

Small plastic tubes extruded of Styron (Dow polystyrene) are being used successfully as a protective blanket over chromium plating baths to minimize the escape of fine spray from the tank. The Udylite Corp. of Detroit, together with the Dow Chemical Co., worked out this idea.

These plastic tubes, closed at each end and resembling miniature pillows, are floated on the chrome bath solution in sufficient depth to blanket the bath and thereby lessen considerably the escape of the fine spray. The tubes move apart when a rack of objects which are to be plated is lowered into the solution; they move back into place around the rack spine, completely covering the acid bath while the objects are being plated. The thicker the surface blanket, the less chromic acid loss. About 1½ lb. of the tubes are necessary for a 1-in. blanket over 1 sq. ft. of solution surface, and 3 lb. per sq. ft. for a 2-in. blanket.

While the Styron tubes save from 50 to 75% of the chromic acid ordinarily lost, the protection it gives plating room employees is also an immense advantage. The use of this protective blanket also reduces loss of heat from the plating bath.

Styron was chosen as the plastic material from which the 3-in. long tubes are extruded because of its exceptional resistance to acids and alkalies, and because,

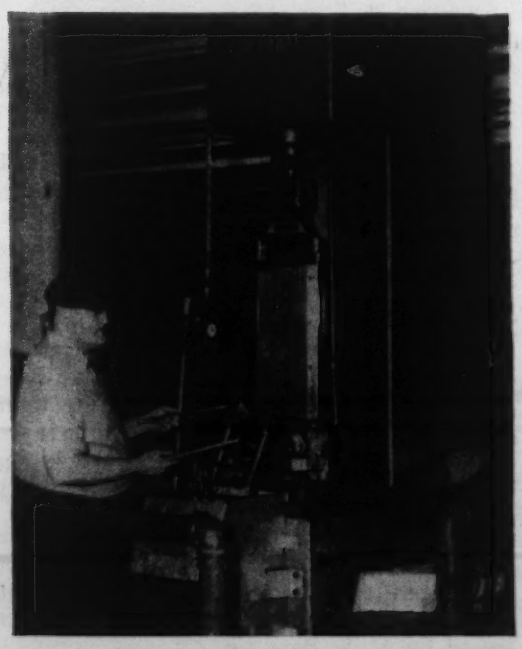
Plastic tubes blanketing chromium plating solution to reduce fine spray.

like most plastics, it is lightweight and smooth textured. The tubes are shatterproof and are not changed in size, weight, appearance or chemical composition by immersion for days in the chrome plating bath.

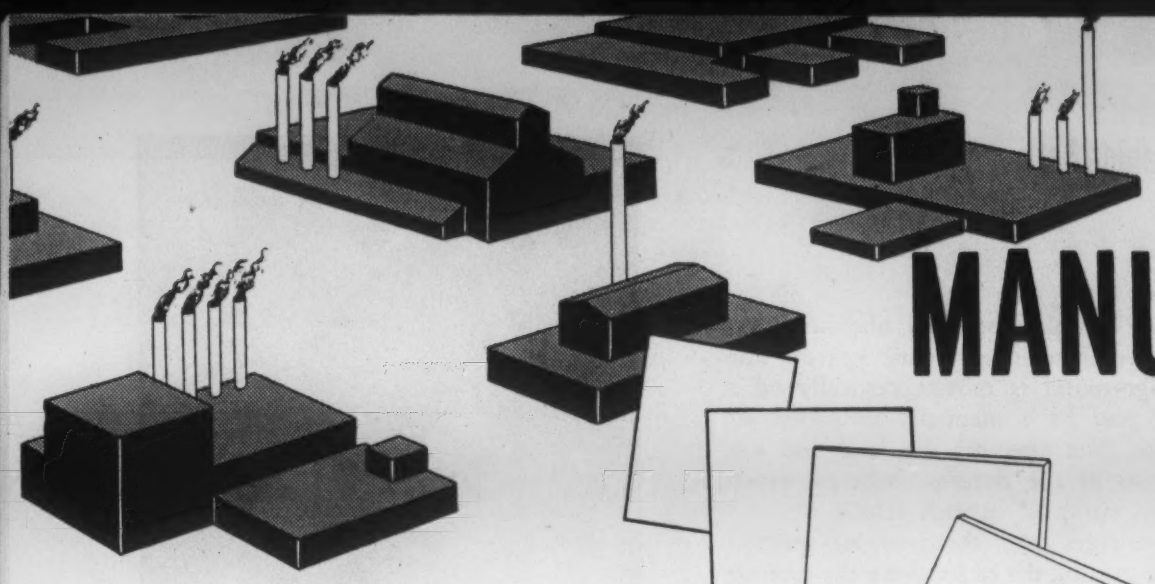
Broaching 20 Notches in One Operation

Converting a steel tube into an automobile parking brake lever with some 20 notches is done in a single machining operation at Willys-Overland Motors, Inc., Toledo. All 20 notches for the rachet mechanism are cut simultaneously with a single stroke of a broaching press.

The accompanying photograph shows the broaching machine, built by Colonial Broach Co., Detroit. The equipment consists of a 6-ton standard broaching press, plus assembled type broach, plus a hydraulically actuated trunnion fixture. Production is some 175 pieces per hr.



The broaching machine used to convert steel tube into brake lever in one operation.



MANUFACTURERS'

Materials

Cemented Carbides. A new revised price list and catalog distributed by Adamas Carbide Corp. discusses cemented carbides—their styles, sizes, tolerances, applications, prices, etc. (1)

Stainless Steel in the Petroleum Industry. The role of stainless steel in the development of the petroleum industry, and its future applications in producing and processing oil, is explained by Allegheny Ludlum Steel Corp. in a 36-page, illustrated bulletin. (2)

Heat Resisting Paint. Technical Service Data Sheet No. 6-2-11-5, one page, discusses Kemick, a heat resisting chemical paint that protects hot metal surfaces even at temperatures above 600 F, produced by American Chemical Paint Co. (3)

Fused Silica and Quartz Products. A complete line of fused silica and quartz products produced by Amersil Co., Inc. is described and illustrated in a 20-page bulletin. (4)

Stainless Steel Fastenings. The large stock of standard and non-standard stainless steel fastenings, ready for immediate delivery, is described in a 4-page, illustrated bulletin offered by Anti-Corrosive Metal Products Co., Inc. (5)

Stainless Steel Tubing. Typical applications of B & W stainless steel tubing are outlined by Babcock & Wilcox Tube Co. in their new bulletin, No. TB-323. Included are the most commonly used Croloy analyses as well as tubing and pipe size ranges. (6)

Phenol and Vulcanized Fibres. Complete data on a variety of standard grades of vulcanized fibre and phenol fibre plate are presented in a 6-page, illustrated folder issued by N. S. Baer Co. (7)

Plastics. A brief outline of the origin, preparation and uses of plastics, and of their importance in our modern living, is attractively presented by Bakelite Corp. in a 36-page, illustrated booklet, No. G-11. (8)

Flexible Metal Hose. Flexonics, a process of controlled bending of thin metals for use under varying conditions of temperature, pressure, vibration and corrosion, is discussed in a new bulletin, No. G-47, offered by Chicago Metal Hose Corp. (9)

Compounded Elastomers. The characteristics and properties of Sirvene compounded elastomers, and their application in the engineering of new products, are presented by the Chicago Rawhide Mfg. Co. in an attractive, 32-page, illustrated catalog. (10)

Precision Molded Plastics. The facilities, experience, equipment and service of the Consolidated Molded Products Corp., producers of compression-, transfer- and injection-molded plastics, are described and illustrated in an 8-page bulletin. (11)

Forged Nuts, Forgings. Large forged nuts starting at 3 in., flat die forgings from 10 to 14,000 lb., and hydraulic pressed forgings to close tolerances are all described and illustrated in a 6-page folder offered by Jos. Dyson & Sons, Inc. (12)

Steel Plate Rings. The facilities of the Lukens Steel Co. for producing any size or type of steel plate ring are profusely illustrated in this 12-page bulletin, as well as a complete line of their products. (13)

Molded Plastics. Typical and varied applications of the molded plastic components produced by the Mack Molding Co., Inc. are described in this 8-page, illustrated bulletin. (14)

Plastic Firebrick. The steps taken to line a ladle or metallurgical furnace with Helspot, a plastic firebrick, are illustrated and described in a 4-page bulletin offered by Mexico Refractories Co. (15)

Protective Coatings. The features, uses and application of a complete line of protective coatings that can be applied like paint to metal wood and masonry are presented by Prufcoat Laboratories, Inc. in a 4-page, illustrated bulletin. (16)

Hard-Facing Guidebook. A comprehensive guidebook offered by the Stoody Co. contains 48 illustrated pages on how to select the hard-facing alloy producing greatest service life, considering initial cost and speed of application. (17)

Permanent Magnets. The use, design and fabrication of permanent magnets is discussed in a new bulletin just released by Thomas & Skinner Steel Products Co. (18)

Stock Tubing. Specifications and prices of a complete line of electric furnace "nickel moly" stock tubing are presented by Timken Roller Bearing Co. in an 8-page, illustrated bulletin. (19)

Methods and Equipment

Blast Cleaning Machine. Five sizes of the Wheelabrator Swing Table, an airless abrasive blast cleaning machine, are described and illustrated in a 20-page bulletin, No. 214-A, published by American Wheelabrator & Equipment Corp. Specifications are included. (20)

Aluminum Bronze Die Repairs. The correct welding procedure for Ampco aluminum bronze die repairs is presented by Ampco Metal, Inc. in a 2-page procedure sheet, No. D-2325. (21)

Rust Preventive. Complete data on a variety of Rustavoid rust preventives that offer protective treatment from the thinnest of residual films for temporary protection to permanent coatings are presented in a 4-page, illustrated bulletin offered by F. E. Anderson Oil Co. (22)

Hydraulic Testing Machine. The Sonntag Model S-10 Universal hydraulic testing machine designed especially for mass production testing is described and illustrated in a 4-page bulletin, No. 182, available from Baldwin Locomotive Works. Specifications are included. (23)

Paint Engineering. A new service to help industrial paint users select the proper paint or coating formulas, as well as the correct mechanical application machinery, is discussed by Bradley Paint Engineers, Inc. in an 8-page, illustrated booklet. (24)

Spacer Unit. This 12-page bulletin profusely illustrates and describes the Man-Au-Trol Spacer, a semi-automatic movable work table that accurately positions work under a fixed spindle for any combination of drilling, boring, reaming or tapping operations, produced by the Bullard Co. (25)

Special Machines and Tools. The facilities of the Bunell Machine & Tool Co. for the precision building of special machines, tools, dies, gages, etc., are profusely illustrated and described in a 4-page bulletin. (26)

New Materials and Equipment

Portable Unionmelt Welding Machine for Light Gage Work

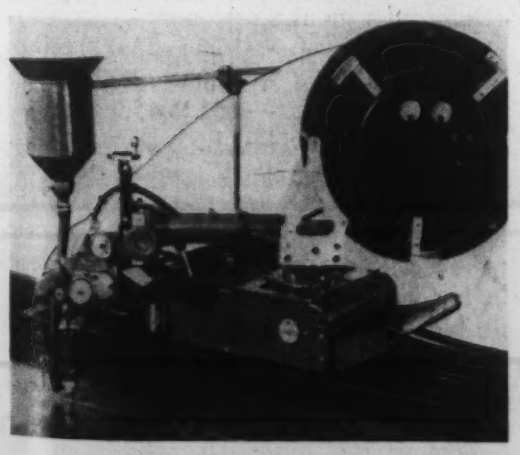
A new portable automatic welding machine, built especially for welding light-gage sheet and light plate by the Unionmelt submerged arc welding process, has been developed by the *Linde Air Products Co.*, 30 E. 42nd St., New York 17.

The machine weighs only 190 lb., and can be moved from one location to another as the work may require. The machine can be placed directly on the work and hand-guided, or it can be mounted on standard track or guided by a small structural angle clamped to the work for production welding.

Extensions are available for lengthening the nozzle assembly when making non-positioned fillet welds or welds below the level of the carriage. The welding head can be swung forward through 45 deg., tilted at any desired angle to either side, or positioned anywhere in a circle around the carriage. The head supporting arm can be extended as much as 5 in. The head also has a vertical adjustment of 5 in., or it can be set to permit vertical motion as the guide wheel follows the surface of the work piece. Small vertical and lateral adjustments for positioning the welding head can be easily and quickly made by means of hand wheels.

Controls are mounted within the plastic rod reel frame, and the welding head and rod reel are mounted on a carriage, which has stepless speed control from 7 to 210 in. per min.

The machine, designated DS-37, will butt-weld, in a single pass, material from 16-gage to ¾-in. thick. It will also make, in a single pass, positioned fillet welds with legs measuring ⅛ to ¾ in.; non-positioned fillet welds with legs from ⅛ to ⅜ in.; and plug welds in material ¼ to 1¼ in. thick. Material of any thickness can be welded by using multipasses. Welding currents up to 1,200 amp. can be applied and coiled welding rods of 3/32- to ¼-in. dia. can be used.



The Unionmelt welding machine, mounted on a standard track, is frequently used for production operations.

New Finishes Resist Corrosion

A new anti-corrosive co-polymer finish for the protection of metal, wood and concrete against corrosion from exposure to moisture, acids, alkalies and many other disintegrating elements has been developed by Industrial P-5 Div., *Watson-Standard Co.*, Pittsburgh 12.

In addition to its chemical resistance, P-5 is free from objectionable paint odors, is non-toxic and dries by evaporation without requiring an oxidation period. It is said to have good thermal stability, is highly resistant to abrasion and scrubbing, and has good aging characteristics.

Two coatings, Carbo Standard White N and T, designed to protect wood, metal, concrete, or brick from weathering, atmospheric corrosion, mildew, and termites are products of *Carbozite Protective Coatings, Inc.*, Greensburg, Pa.

White N, a semi-glossy white, is resistant to weathering and to mild acids and alkalies in the atmosphere. White T is designed to combat mildewing. The base for both is an alkyd varnish to which are added zinc oxide, fillers, solvents, and 100% titanium dioxide pigment.

They may be applied either by brushing or by spraying. Coverage is approximately 200 to 250 sq. ft. per gal., and drying time is 4 to 6 hr.

● Silicon monoxide is now available for hardening evaporated metal films on glass. A thin layer of silicon monoxide is evaporated onto the metal film by high vacuum evaporation techniques. Subsequent heating of this film converts it to silica, resulting in a surface having approximately 100 times the abrasion resistance of an unprotected metal film. Experimental quantities of high purity silicon monoxide in granular form suitable for evaporation are now being produced by *National Research Corp.*, Boston 15, Mass.

Belt Sling Protects Thin Wall Tubing in Pickling Bath

A new type pickling sling has been developed especially for the handling of thin wall tubing in the pickling bath. A product of the *Cambridge Wire Cloth Co.*, Cambridge, Md., it can be used for rod and bar stock as well as tubing.

The sling is of mesh construction with flat, even surfaces that do not protrude to collapse the tubing or scratch the finish. In can be placed around the tubing and hooked into a hoist in one operation. The sling is made in any desired length or width of Monel, Inconel, or other materials to resist the corrosive action of the pickling solution. The Monel sling will handle 5 tons of stock for pickling.

This pickling sling is designed to prevent collapsing thin wall tubing and won't scratch the surface. It is also useful for rod and bar stock.

New Welding Rods Announced

Below are brief descriptions of some recently announced welding electrodes for a variety of applications.

Wilson Welder & Metals Co., Inc., 60 E. 42nd St., New York 17. Wilson No. 575 all-position electrode with a high nickel core wire and heavy extruded coating has use for machinable welds on cast iron. Has special use in automotive field for welding castings and production line repair work. Ordinarily preheating is not necessary. Available in 5/32-in., ⅛-in. and 3/32-in. dia. and may be used on either a.c. or d.c. Also announced, a new line of stainless steel electrodes in a full range of grades and diameters. They have extruded lime type coating for d.c., or (except for the straight chrome analysis) are obtainable with a lime-titania type coating for a.c. or d.c.

Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30. Electrodes for welding low alloy cast steel or low alloy high tensile strength rolled steels in all positions, with a.c. or d.c. reverse polarity, are available in 4 dia. from 3/32 to 3/16 in. They are designated ACP-MO. Can be used with a.c. or with d.c., reverse polarity. They should be used for vertical or overhead welding although produce equally satisfactory results in making horizontal fillet and flat position welds. Welds made with this electrode meet requirements of AWS-ASTM tentative specifications for Iron and Steel Arc Welding Electrodes Classification E-7011.

Harnischfeger Corp., Welding Div., Milwaukee 14, Wis. Nicast, an all position electrode, is suitable for repairing broken castings, building up worn castings, correcting machining errors and welding cast iron to steel. The electrodes are available in either ⅛- or 5/32-in. sizes.

The *McKay Co.*, 1005 Liberty Ave., Pittsburgh 22. Hardalloy, a d.c., reverse polarity arc welding electrode, provides weld metal which is highly resistant to impact or abrasive wear in hard-surfacing applications. The weld metal as deposited tests 59.0 Rockwell C hardness and is capable of being heat-treated for machining or grinding, and subsequently re-heat treated to restore it to its as-deposited hardness. It is available in five sizes from 3/32 to ¼ in.

All-State Welding Alloys Co., Inc., 96 W. Post Rd., White Plains, N. Y. A new cast iron solder rod for repairing cracks in cast iron. Rod produces corrosion-resistant welds; it melts at 600 F and tins easily. The rod is known as All-State No. 7.

● *Lindberg Engineering Co.*, 2444 W. Hubbard St., Chicago, is now manufacturing a line of air cooled transformers. These transformers have been developed for use with electric furnaces, for testing functions, and various applications requiring heavy current. Sizes obtainable are rated from 1 to 100 Kva, up to 600 volts, single phase, 3 phase, or 3 to 2 phase.

Fiberglas Mat for Plastics Reinforcement

A new Fiberglas mat for use as reinforcement in the manufacture of laminated plastics products, and in the production of flat plastics sheets, has been announced by *Owens-Corning Fiberglas Corp.*, Toledo, Ohio. The mat, known as Code T36, is formed of cut lengths of glass textile fibers, bonded with a resin.

The material is pliable, without fluffiness, and retains the strand integrity of the fibrous bundle. Weight is 1 oz. per sq. ft. Preliminary test results, while not conclusive, indicate the following range of strength properties for plastics products reinforced with the new mat:

Tension	— 20 to 23,000 psi.
Compression	— 20 to 22,000 psi.
Flexure	— 35 to 45,000 psi.
Specific Gravity	— 1.55
Impact	— 20 to 22 ft./lb.

Two types of the mat are available bonded with a thermoplastic resin compatible with the polyester laminating resins or bonded with a thermosetting resin compatible with phenolic and melamine laminating resins. The former can be heated before impregnation (200 to 225 F) and preformed to the desired shape.

Because the binder is soluble in the polyester laminating resins, the mat can be draped in the mold after impregnation, reducing the need for tailoring.

New Polishing Lathe Has Wide Range of Uses

The first model in a new line of polishing lathes for jewelers, plastic manufacturers, platers, foundries, tool rooms and laboratories, is being introduced through *Ralph Hochman & Co.* of Newark, N. J.

The standard machine, Model 400, is equipped with a self-contained dust collecting unit, and ball bearing 1725-rpm. motors of various sizes from ½ to 3 hp. of standard current characteristics. These motors operate both the polishing head and dust collecting units.

Dust is drawn from the surface of the machine by a 4-in. duct in each collector. A removable receptacle on the intake side of the exhaust fan traps any foreign object and prevents it being drawn into the system. The dust-ladened air is cleansed by being passed through water and is returned to the work-room through three louvers in each side of the collector.

Spindles are tapered, but can be replaced by the straight type if desired. Each wheel has its own dust collector. A fabric dust-bag, immersed in water, on the exhaust end of the fan housing, can be readily removed and cleaned. A single motor operates all the processes of the machine.

● A new light-weight and small size rotary vane pump has been announced by *Romec Pump Co.*, 162 Abbe Rd., Elyria, Ohio. This self-priming positive displacement unit is so designed that by varying materials and accessories it can be used to pump fluids from a watery viscosity to No. 60 S.A.E. oil. It has a capacity of 75 gal. per hr. Metal, chemical and plastic industries should find it applicable to many of their pumping problems.

Motor Driven Shaker Screen For Deburring Barrels

A portable motor-driven shaker screen for use with deburring and finishing barrels is being produced by *Almco, Inc.*, Albert Lea, Minn. This unit separates the finished work from the tumbling medium, eliminating hand screening and sorting.

The screen is driven by a ½-hp. or ⅓-hp. motor, and vibrates in an elliptical path at 380 reciprocations per min. Length of movement is adjustable from zero to ¾ in. to meet all requirements. Interchangeable wire screens are available in standard sizes from 3/64-in. to 2¼-in. openings, and are removed simply by pushing up and slipping out from between retaining lugs at each end of the frame.

One screening unit will normally serve 3 or 4 barrels. Its over-all height of 24 in. (exclusive of the handle) permits this unit to be placed directly under Almco tumbling barrels to separate the load directly on discharge; and there is sufficient clearance beneath the screen for a mobile hoist pan to receive the screened material.

Equalized Heat and Automatic Control Featured by New Oven

A new electric laboratory oven, the KH 1200, has been developed by *K. H. Huppert Co.*, 6830 Cottage Grove Ave., Chicago. It features equalized heat by means of a simple double-venting device.

The automatic hydraulic-electric temperature control is said to control temperature to an accuracy of ± 1 C at any desired point within the furnace range to 420 F. This new oven is particularly adapted to general analytical work, and for unlimited heating, drying, baking and testing. The oven has a stainless steel interior.

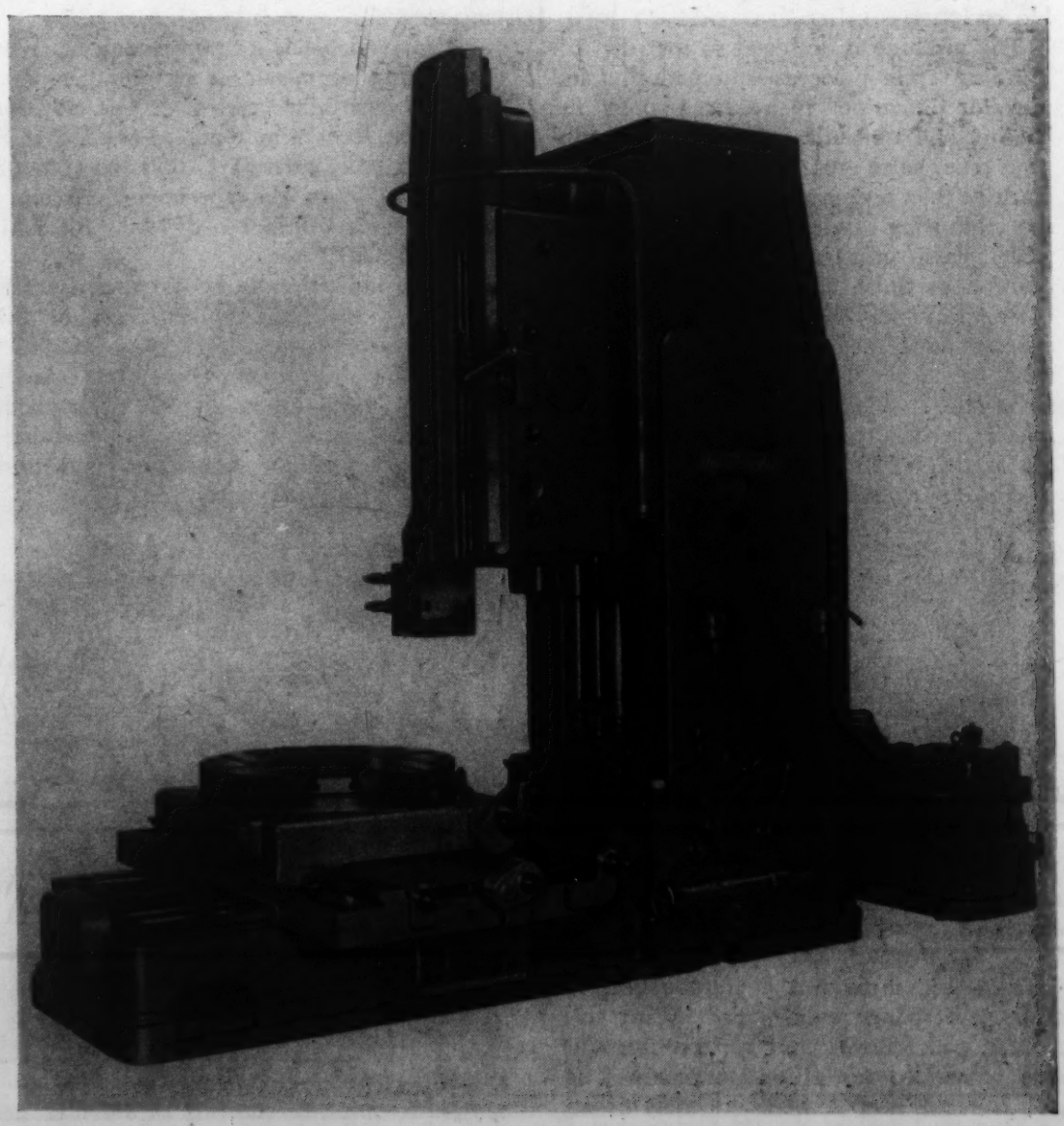
The dimensions are: I.D. 12 by 10 by 10 in. and O.D. 15⅜ by 21¼ by 15 in. It is equipped with two adjustable vents having stainless steel slides to control exhausted air and equalize temperature inside of oven.

Hydraulic Slotters Available in Two Sizes

Two large size hydraulic slotters with 36-in. and 48-in. strokes have been introduced by the *Rockford Machine Tool Co.*, Rockford, Ill. The ram may be set for travel in a vertical plane or in any tilted plane up to 15 deg. off-vertical.

Ram cutting and return stroke speeds are infinitely adjustable over a wide range to take full advantage of all work conditions. Because the ram is hydraulically driven, stroke lengths are easily set by valve control.

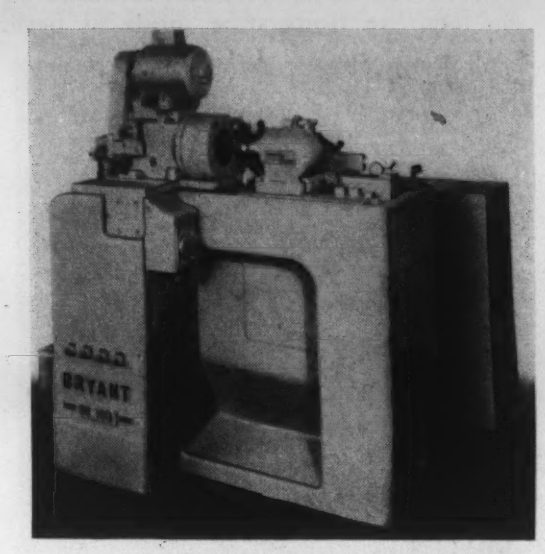
The cutting speed range for the two machines is 0 to 80 ft. per min. The table travel is transverse 30 in., and longitudinal 42 in.



Shown here is the hydraulic slotter with 36-in. stroke. Also available is a 48-in. stroke model.

Internal Grinder Designed for High Production Bore Grinding

A new automatic internal grinder, particularly designed for high production grinding of bore diameters from ¼ to 3 in. up to 4 in. deep, has been announced by the *Bryant Chucking Grinder Co.,* Springfield, Vt. Designated the No. 109, the grinder will swing work up to 9 in. and is suitable



The hydraulic and electronic controls on the internal grinder make it possible to have the grinding and trueing action timed to a split second.

for such jobs as ball bearing races, gears, rolls, bushings and other small parts which can be produced most profitably in large quantities. An important feature is the hydraulic and electronic control arrangement that provides for selective, infinitely variable cycles.

The machine is designed so that the full grinding cycle proceeds automatically and operator attention is required only for loading and unloading the work and tripping the valve to start the cycle. The machine then operates automatically through the following cycle—rough grind, true wheel, finish grind and return to chucking position as finish size is reached.

By providing d.c. motors to supply driving power to the cross feed and the work drive spindle, an infinite number of feeds and speeds are available. With this grinder wheel, speeds up to 100,000 rpm. can be attained to assure the efficient surface speeds so necessary when grinding small bores. Provision has also been made for a balanced, belt-driven wheelhead, giving speeds from 200 to 2400 rpm.

● Machine sanding of curved surfaces is now possible with the portable electric sander (Sterling 1000) produced by *Sterling Tool Products Co.,* 363 E. Ohio St., Chicago 11, through the introduction of their new sponge rubber pad. With this flexible pad, convex and concave surfaces may be sanded easily and uniformly. The pad is faced with a 1-in. thickness of an oil resistant, cellular type sponge rubber. The abrasive sheet is placed over the flexible surface of the pad in the same manner as is done with the standard sanding pad.

Fatigue and Creep Machines for Normal and High Temperatures

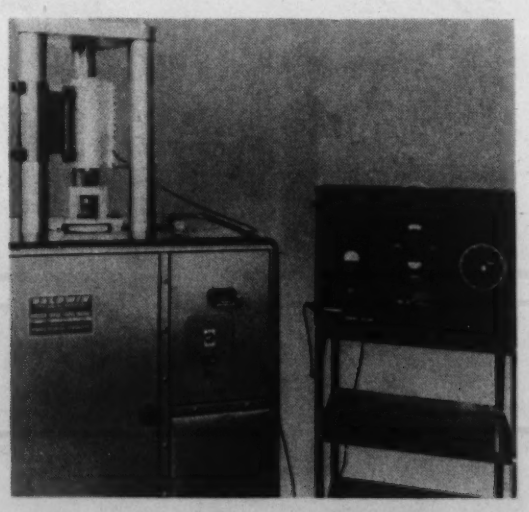
A new fatigue machine, model SF-4, equipped for tension-compression testing both at ambient and at high temperatures, has been developed by the *Baldwin Locomotive Works,* Philadelphia 42.

Maximum capacity of the new machine in either direction is 10,000 lb.; static preload capacity, 0 to 5,000 lb.; alternating (dynamic) load capacity, plus or minus 5,000 lb.; speed of testing, 3600 load cycles per min.; maximum movement of reciprocating platen, plus or minus 1/16 in. Weight of the machine is 3,000 lb. and overall dimensions 43 by 43 by 75 in. high.

The dynamic load is applied by means of a revolving eccentrically disposed mass. The eccentric is of the micrometer screw type, permitting fine adjustments quickly by hand, and the amount of eccentricity is read like a micrometer, graduations reading in units of pounds. The entire working mechanism is seismically suspended on soft tension springs which absorb over 99% of the vibratory forces. The machine can be installed on any floor capable of supporting its weight without disturbance to surroundings. Dynamic load remains constant and overall variations are less than plus or minus 2%.

Also available is a creep testing machine for testing of metals at elevated temperatures to determine creep rate. The machine is of the lever arm type, of welded steel construction. Capacity: 12,000 lb. (60,000 psi. on 0.505-in. dia. specimen). Accuracy guaranteed is within 1% of load (A.S.T.M. specifications).

Strain indication is by extensometer attached at pin holes at shoulders of the specimen and is read directly to 0.000025 in. on a motor-driven revolution counter by means of a follow-up contact method. The extensometer will operate to rupture. The accuracy of the strain unit is within 0.00005 in., approximate.



Overall view of the fatigue machine for tension-compression testing at ambient or high temperatures.

High-Vacuum Furnace for Materials Reactive to Gases

For the heat treatment of materials which are highly reactive toward gases, a high-vacuum furnace has been developed by *Eitel-McCullough, Inc.,* 1570 San Mateo Ave., San Bruno, Calif. Capable of continuous operation at temperatures in the 3300 F region, the standard type consists

This high vacuum furnace operates in the 3300 F temperature region.

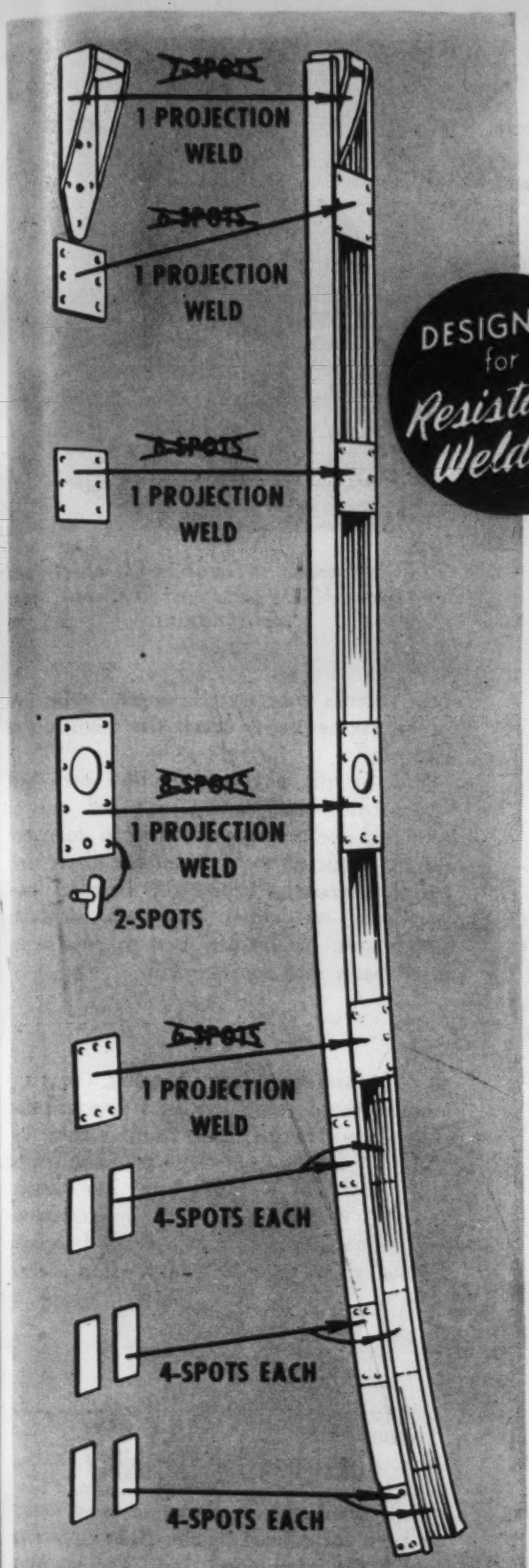
of three chambers integrated into a single enclosed cubicle. Cycling circuits are incorporated so one chamber can be in the treatment phase while one is under preliminary pumping and the third is being reloaded.

With this furnace it is possible to attain a production vacuum as high as 5×10^{-6} mm. of mercury. Heating of the furnace is accomplished by large-diameter tungsten elements which involve low voltage. This minimizes ionization problems which are particularly troublesome in induction-heated vacuum furnaces and permits a rapid approach to full temperature.

Interlocking safety devices are provided to protect furnace parts against temperature extremes and the heating filaments against burnout from operation at too high a gas pressure. Program timers control the operating cycle and provide a means for presetting the treatment routine.

Consuming a total of 15 kw. of power, the three-chamber unit has a total treating capacity of 175 cu. in. Work to be treated is ordinarily handled in molybdenum containers which are inserted and removed from the furnace chambers fully loaded for rapid processing. Where a wide variety of work is to be handled, separate containers can be used for each type of treatment, reducing contamination from one to another.

● A d.c. amplifier for use with their magnetic direct inking oscillographs has been announced by the *Brush Development Co.,* 3405 Perkins Ave., Cleveland 14. Known as Model BL-913 D-C Amplifier, the power requirements for this instrument are 105 to 125 v., 60 cycles, 125 w.



DESIGNED for *Resistance Welding*

Producing 50 bus pillars an hour from these stampings with 59 spot welds was good production. Getting 100 an hour with 5 projection and 26 spot welds was better.

IT PAYS TO WELD

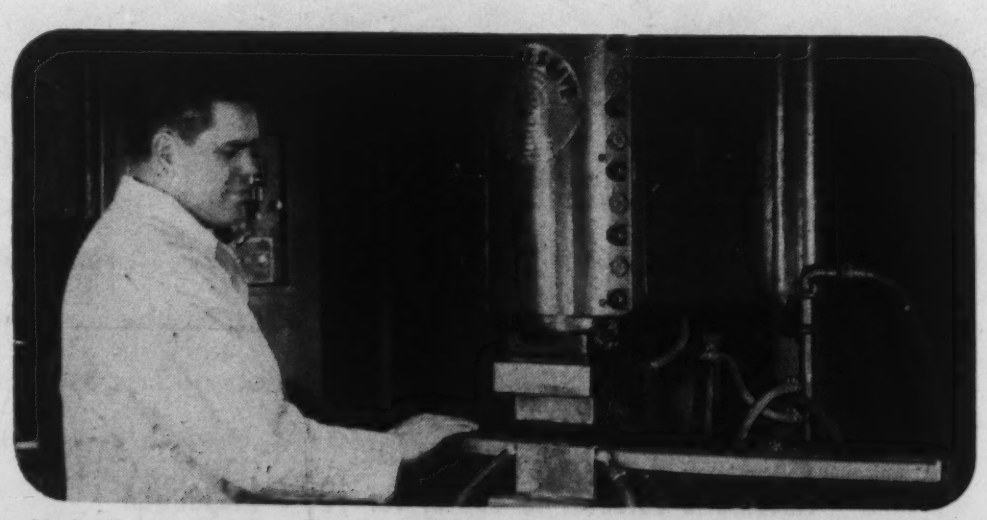
PROGRESSIVE SHOWED THEM HOW TO ... double production ... cut cost in half by cutting 33 operations to 5

Hawthorne Metal Products Co. of Detroit had a contract to produce reinforced stamped pillars for bus bodies. Their cost was low since they were using spot welding to assemble the 13 separate stampings at 50 an hour

BUT—after Progressive's Process Engineering Department studied the design and recommended a few minor changes in 5 of the stampings—production jumped to 100 per hour—doubling output per machine hour and cutting assembly cost in half.

Those simple changes made it possible to assemble each of the five largest stampings to the bus pillars proper with just one projection welding operation on each part—five operations instead of 33!!

That's why it pays to call in Progressive's Process Engineering Department. We will be glad to work with you, too.



Here the center bracket is being welded (at eight projections at one time) with a single shot in a Progressive Press Welder.

CABLE ADDRESS "PROGWELD"

MEMBER RWMA RESISTANCE WELDER MANUFACTURERS ASSOCIATION

PROGRESSIVE Welder Co. 3050 E. OUTER DRIVE • DETROIT 12

RESISTANCE WELDING EQUIPMENT

Turn-Table Type Machine Centrifugally Casts Welding Rods

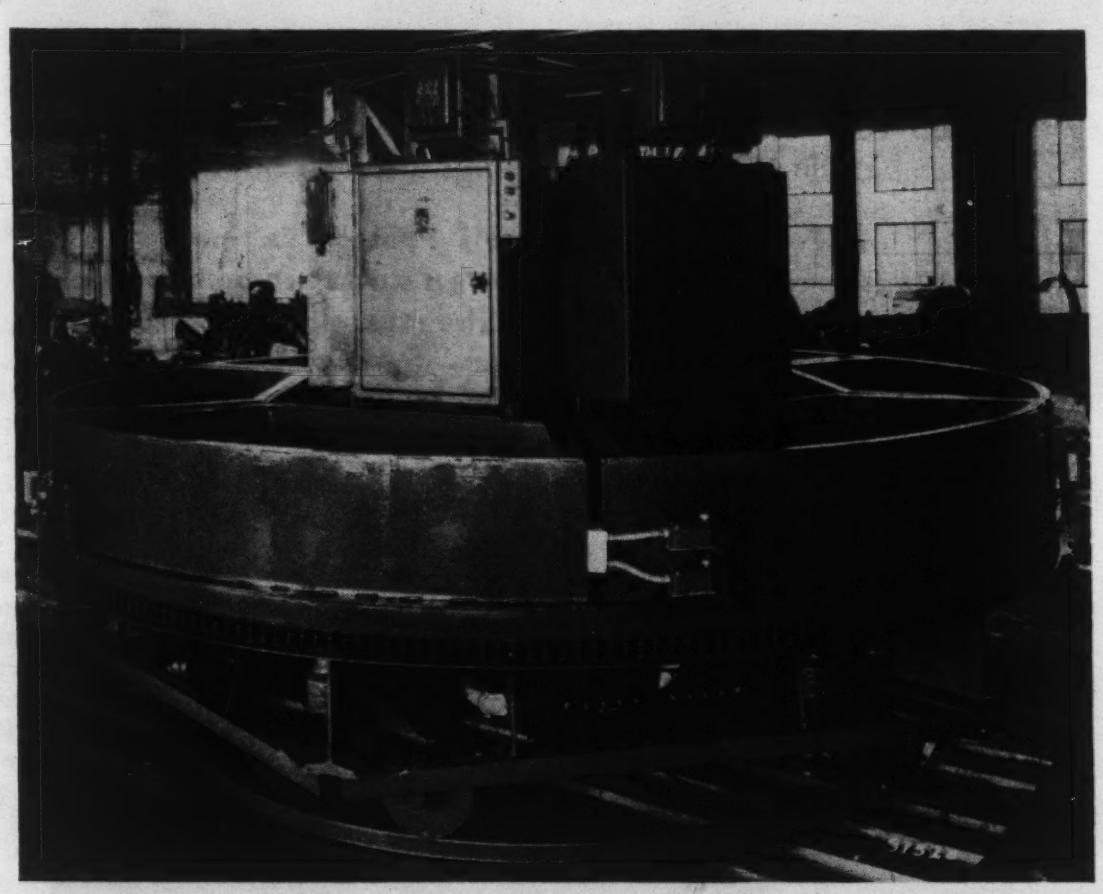
An interesting machine for high production of centrifugally cast welding rods has been designed and built by the *Centrifugal Casting Machine Co.,* Tulsa, Okla. Besides producing welding rods, this machine can be used for any type of centrifugal casting for which high production is desired.

The machine is a turn-table type, having six individual casting machines or spindles mounted on one turn-table, thus automatically bringing each spindle in turn to the pouring station, the casting removal station, the mold preparation station, etc.

While the production rate of the machine can be varied and is determined by the size of rod produced, a production of approximately 1500 lb. per hr. of finished rods is obtained. The rods require no sand blasting or other type of cleaning; they merely are cleaned of any fins which occasionally occur.

The turn-table proper is approximately 14-ft. in dia., and is driven by means of a chain drive, through a reduction gear and variable speed motor unit. The speed of the turn-table may be varied from ½ to 2 rpm.

The turn-table drive mechanism is provided with controls that will automatically stop the turn-table so that each spindle in turn is stopped at its proper station for the various operations incidental to making the castings. To accomplish this, provision is made for the table to stop at each 60 deg., delay at each stop for a pre-set period of time, then move on to the next stop. This permits each spindle to be stationary during each casting operation. It is possible, however, to adjust the controls so that the turn-table will rotate continuously at a desired rate of speed. Such procedure is desirable for certain types of casting operation.



This unique centrifugal casting machine is designed primarily for welding rod manufacture, but is also applicable to other casting jobs.

Automatic Selector Is Useful for 100% Inspection

An automatic hopper-fed roll selector for 100% inspection of length and diameter of small precision parts such as roller bearings, dowel pins, chain links, and similar products has been developed by the *Sheffield Corp.* of Dayton 1, Ohio. It can be adjusted to permit an infinite number of different sizes of parts within the capacity of the machine to be gaged quickly to a tolerance of 0.0005 in.

The flexibility which permits such a large number of different size parts to be gaged is accounted for by its range of adjustment, 7/32 to 31/32 in. on diameters and from 9/32 to 3 in. on lengths.

After setting up the automatic roll selector, using minimum and maximum masters or two parts known to be the correct size, the parts are placed in a hopper. A reciprocating device picks up the units, and by means of a gravity fed slide they proceed to the gaging position. One gaging

This automatic selector will check and segregate 3600 parts per hr. into four classifications.

head checks the overall length while two other gaging heads check the diameters at each end.

During the gaging operation each part is classified and segregated into one of four classifications—parts within tolerance limits, diameter within tolerance limits and length oversize, oversize on diameter, and undersize on either or both diameter and length. Chutes are used to pass segregated parts into separate bins.

● *Kennametal, Inc.,* Latrobe, Pa., announces the development of a standard line of internal radius tools and blanks for rounding the corners of machine parts. Such tools have heretofore been made special to suit individual requirements. As supplied, they are form ground to hold contour when reground on the top surface only.

Hydraulic Press Brake Designed for Flexibility

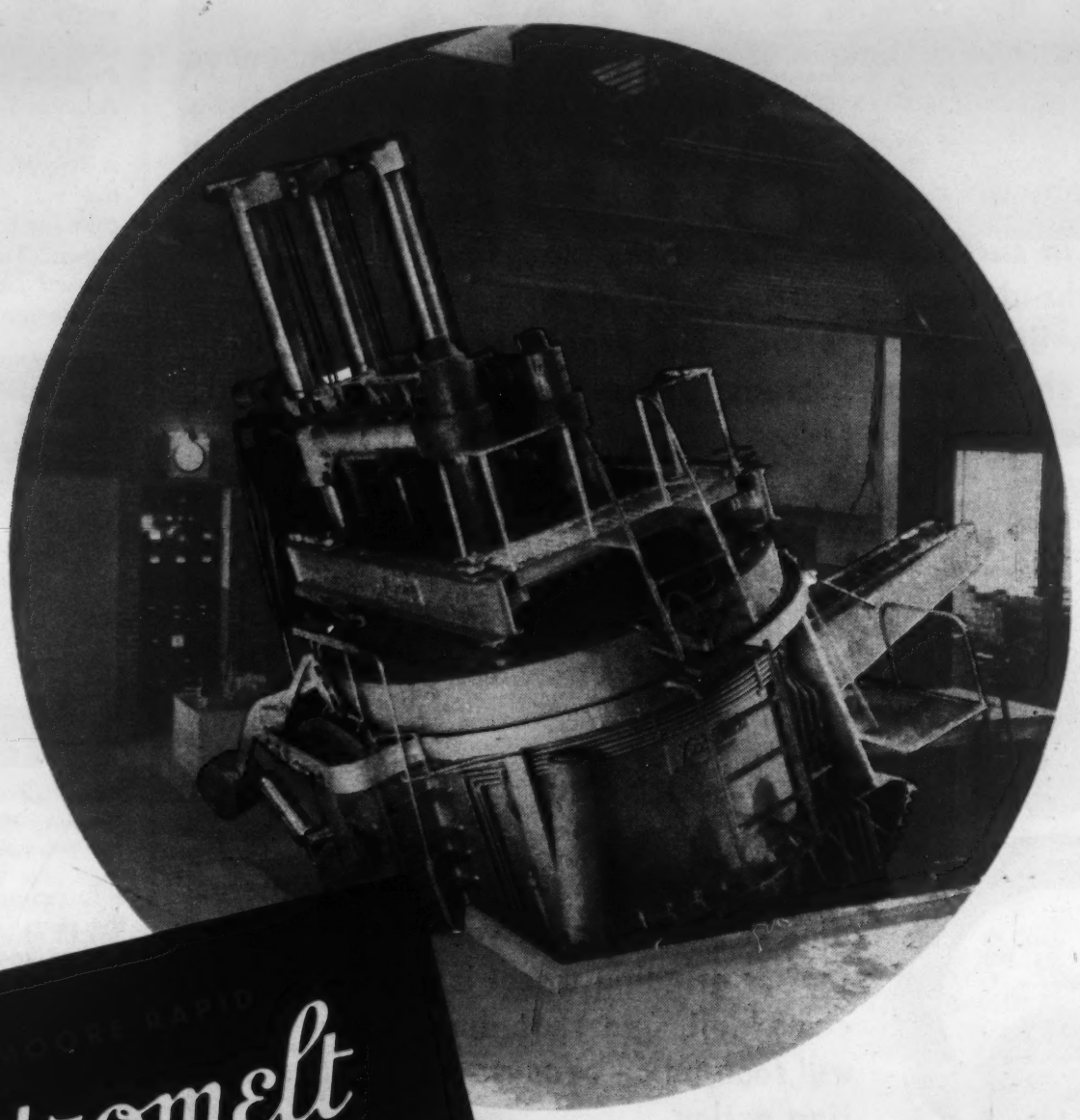
A hydraulic press brake of new design has been introduced by the *Beatty Machine & Mfg. Co.,* Hammond, Ind. The machine, Model No. 300, is of 300-ton capacity.

This machine is adaptable to V-bending, flanging, pressing and straightening operations. Into this machine have been incorporated factors for increasing productive speed: the ram advances at a maximum of 310 in. per min., returning at 285 in. per min., while pressing under full load takes place at 14 in. per min. These speeds are variable between zero and maximum.

Balanced control of the ram is achieved in the design of this machine through an equalizer which brings the ram down parallel with the bed through the use of racks and an idler pinion shaft.

The machine is of the open throat, closed housing type and is built in capacities from 200 to 600 tons, and in sizes from 8 ft., 6 in. to 12 ft., 6 in. between housings. Stroke control features are incorporated to allow for operating in any portion of the stroke between the top and bottom limits.

flexibility is economy



Size "OT" Lectromelt furnace tilted backward in slagging position.

Lectromelt

For large heats, small heats or divided heats—for ordinary irons and steels or for alloys—Lectromelt furnace does the job. The heats are quick, the analyses more easily controlled. Flexibility such as this provides real economy, makes Lectromelt ideal for shops requiring a large variety of castings or ingots.

Write today for complete details.

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PITTSBURGH, . . 30 . . PENNA.

How to catch **DIMENSIONAL ERRORS**

BEFORE THEY OCCUR...

With Tremendous Savings in Time and Cost

This new technique of quality control offers tremendous savings wherever parts are produced in quantity by machining operations—for it gives positive warning of dimensional changes ***before they take place!***

Change in surface roughness is the clue, since it directly indicates the dulling of cutting tools or grinding wheels which results in dimensional errors. The ***start*** of defective cutting action is shown by an ***increase in surface roughness,*** and is quickly determined as follows:

1 Take Profilometer readings of finished pieces, and note the roughness readings along the length of the work area. These readings are made ***right on the production line,*** or even in the machine—and ***without cooling the work*** as required for precision gaging.

2 When the ***range*** of roughness starts to increase (as shown directly on the meter dial in microinches), you know that the tool or grinding wheel is starting to become dull, and that dimensional errors will soon follow because of defective cutting action.

3 Shortly thereafter, when the ***average*** roughness begins to increase, as well as the range, you know that the work will no longer be within required dimensional limits.

This simple procedure enables you to ***prevent*** errors ***before they occur*** —and it can be applied to practically any surface that can be produced by normal machining methods. The initial cost of the Profilometer is soon repaid by resulting savings in production time and elimination of rejects.

May we send you descriptive literature?

The PROFILOMETER
TRADE NAME REGISTERED

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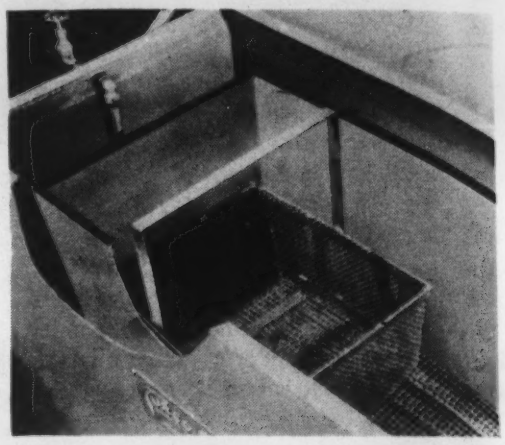
ANN ARBOR • MICHIGAN

Improved Metal Cleaning Agents and Equipment Announced

Cold Tank Cleaner

Fast, thorough removal of oil, grease, chips and other foreign matter that collect on parts during machining, drilling, boring, grinding and similar production operations is claimed for the new cold tank cleaner now being produced by *Turco Products, Inc.,* 6135 S. Central Ave., Los Angeles 1, Calif.

The system, called the Turco Turbulator, is actuated by air volume, pressure differential and gravity, and cleans parts with a combined liquid scrubbing and solvent action. Tiny metered orifices release compressed air which induces a flow of liquid in the inner tank. The cleaning compound



View of the Turco cold tank cleaner, showing the wire basket in which the parts to be cleaned are placed.

is forced under pressure through and around the parts, cutting each thin film from the surface and depositing particles in a static sludge compartment. Only clean compound returns to work on the next film until the fluid action has scrubbed its way to the bare metal.

There are four models for cleaning anything from a typewriter to the largest diesel motor block. Working space ranges from 1 ft. 6 in. by 1 ft. 6 in. by 1 ft. 4 in. (smallest tank) to 6 ft. 6 in. by 3 ft. by 2 ft. 10 in. (largest tank) with working capacity ranging from 52 gal. to 765 gal.

Gas-Fired Cleaning Tank

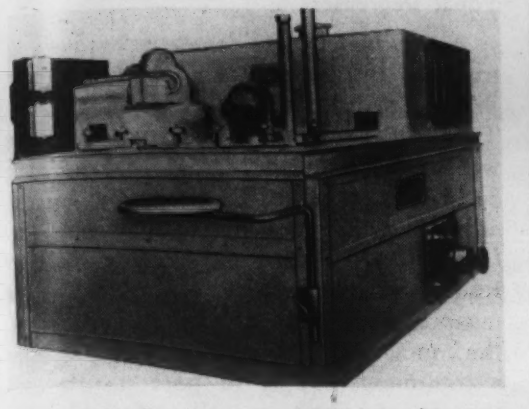
A new gas-fired tank for cleaning metal parts in industrial, automotive plating and other plants is now being manufactured by the *D. C. Cooper Co.,* 1467 S. Michigan Ave., Chicago 5. The same tanks are also available equipped with steam coils where steam heating is desired. The tank may be used in cleaning large and small parts, as transmissions, motor blocks, tractor parts, brake drums, carbureters, tools, nuts, and bolts. The tank may also be used for stripping paints, baked enamel and lacquers from steel and iron parts.

The unit is equipped with 4-in. heating pipes in the bottom of the tank. Fumes are removed through a duct which extends the length of two sides and the back of tank, to which an exhaust fan can be connected. The tanks come complete with thermometer, drain, overflow connections, and can be equipped with an automatic agitating device.

Ball Bearing Washing Machine

A new machine has been developed by

the *Mabor Co.* of Clark Township, Rahway, N. J., for the processing of ball bearings. The variable speed conveyor of the equipment is a link chain affair, wound around a series of sprockets supporting vertical pyramidal holders which accommodate the ball bearings. The races are rotated con-



This ball bearing washing machine is designed to enable cleaning the hidden areas of the races.

tinuously by means of the friction strap and the eccentric sprays which are directed between the two races.

The equipment may be used with any spray treatment, utilizing one, two or three different sprays. From 1500 to 3000 ball bearings, in sizes up to 6 in. in dia., can be handled per hr. in the machine. Loading and unloading in some cases can be made automatic. A blow-off and dryer attachment can be furnished.

The solvents used are emulsion or oil base cleaners, such as kerosene or similar compounds, to prevent the possibility of rust formation. The solvents are also continuously filtered to eliminate the return of harsh abrasives which are damaging to the units being processed.

The same equipment can be utilized for production runs of other parts, with or without rotation under sprays, and with or without blow-off and drying.

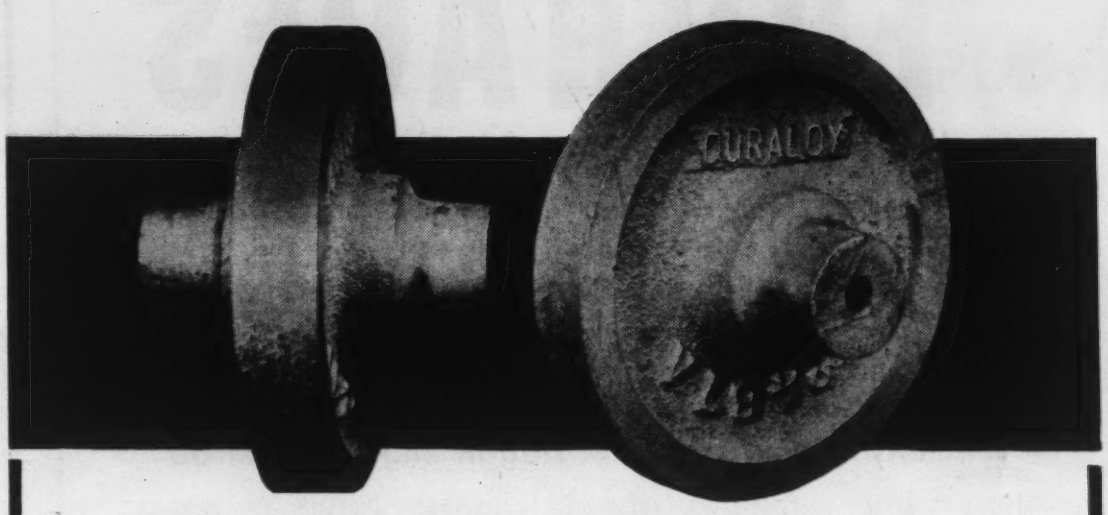
Low Cost Parts Cleaner

A new low cost unit for cleaning dies and small assemblies between machining operations, is offered by the *Gray-Mills Corp.*, 1948 Ridge Ave., Evanston, Ill. Known as the Agitor Jr., the unit has an average

This low cost cleaning unit is handy for small parts cleaning.

DURALOY

HIGH ALLOY CAST ROLLER . . . Weight 1 7/10 pounds



25% Chromium and 12% Nickel . . . these are the principal elements selected to provide these small rollers with the heat-resisting strength to carry the heavy loads in an annealing furnace.

But there's more to producing consistently sound castings than knowing which and how much of the several alloying elements to use. High alloy foundry experience is even more important. Shop facilities as well as quality and conditioning of the molding sand used count heavily toward satisfactory castings. These and other important contributing factors can be found in the background of the casting service offered by Duraloy Metallurgists and Foundrymen.

We would like to produce *your* high alloy castings. May we quote on your next requirements?

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Any size—any cycle—gas, oil or electrically heated.

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operating capacity of 4 gal. of solvent. It is equipped for air-agitation and comes with a large basket and also a small fine mesh basket for very small parts. It can be used as an independent unit on the shop bench or as an auxiliary unit on larger cleaners which are used for general parts cleaning.

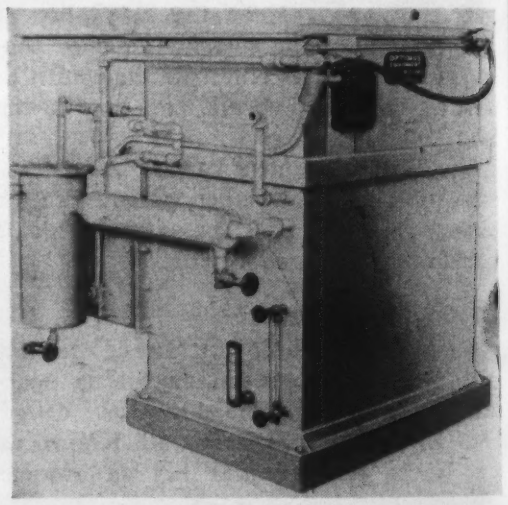
Vapor Degreaser

A new metal parts degreaser has been introduced by *Optimus Equipment Co.*, 105 Water St., Matawan, N. J. It is known as Type OP-1-48, and is designed for use with trichlorethylene. Unit is fabricated of 3/16-in. steel plate. The body and internal auxiliaries are hot dip galvanized after fabrication. Heating and cooling coils are readily removable for cleaning and maintenance. The unit acts as a still to recover the contaminated solvent, thereby providing a continuous supply of pure distilled solvent for the spray as well as for the vapor phase.

This degreaser can be used for degreasing of metal parts prior to further finishing operations in the process of manufacture, or it can be used for metal parts degreasing in maintenance operations.

Chips and insoluble impurities and buffing compounds that have been worked into sharp corners or crevices can be removed by the use of a spray of the solvent directed at the work. A hand spray line made of special woven metal hose is supplied for this purpose.

Work clearance of this degreaser is 45-in. length by 27-in. width. Overall dimensions



Heat to vaporize the solvent in this vapor degreaser may be supplied by either steam, gas or electricity.

are approximately 48-in. width by 48-in. length by 60-in. height. Unit has a capacity of handling 200 lb. of steel per hr.

A new cleaner has just been announced by *Optimus Detergents Co.*, 100 Water St., Matawan, N. J. It is a white, free-flowing powder, named Optimus No. 100, and is completely soluble in hot or cold water. It is a balanced blend of mild alkaline materials, including special water softening ingredients. It is free rinsing and at low concentrations is soft on the skin.

An important application of this new product is in power spray washing machines. Here it is used at concentrations of ½ to 2 oz. per gal. at temperatures from 130 F to boiling. It is effective in removing light oils, grease and dirt, and may be used on ferrous or nonferrous metals. Electro-cleaning can be done with Optimus No. 100 where a cleaner of highly stable electrical conductivity is desirable.

Synthetic Detergent

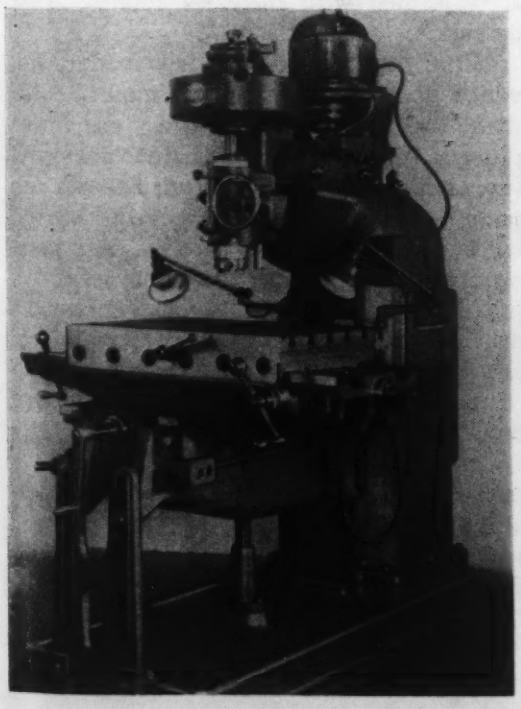
A new modified sulfate detergent with 31% active ingredient for a variety of applications has been developed by *Alrose Chemical Co.*, 180 Mill St., Cranston, R. I. The material may be used for the formulation of industrial detergents for cleaning metals. It is a free flowing, off-white granular powder and yields smooth pastes on dilution with small amounts of water. It remains clear in the presence of calcium, magnesium and many heavy metal salts.

● A cadmium nickel alkaline storage battery which combines advantages of lead acid and nickel iron alkaline batteries is being introduced to industry by *Baker & Co., Inc.*, Newark 5, N. J. Used in Europe for the past 20 years, the cadmium battery has application in a wide variety of industries, including marine, railway communications, food processing, radio and radar.

New Vertical Milling Machine Features Adjustable Ram

A new, heavy duty milling machine suitable for high-speed milling, routing, and die sinking work is being offered by *Reed-Prentice Corp.*, Worcester 4, Mass. It is suitable for work in plastic and rubber molds, die casting dies, and forge dies.

The head is mounted on a horizontal ram for a wide range forward and back. With a large table the range is 32 in. by 22 in. and a throat depth of 30 in.



In order to provide a wide range forward and back, the head of the milling machine is mounted on a horizontal ram.

The machine is powered by a 3-hp., 1200-rpm., 60-cycle motor mounted on the ram. The drive to the spindle is by Vee belt direct from motor to spindle. Ten speeds may be obtained with open belt within the range of 400 to 2600 rpm., and five speeds may be obtained with back gears within range of 133 to 320 rpm.

TO MULTIPLY THE RANGE OF YOUR PYROMETER INSTRUMENTS

ENGELHARD manufactures a complete range of assembled thermocouples consisting of thermo-elements with insulators, protection tubes, terminal heads, couplings and various accessories. Thermo-elements may be platinum vs. 90% platinum 10% Rhodium, Reclaiming Platinum vs. Platinum Rhodium, Chromel vs. Alumel, Iron vs. Constantan and Copper vs. Constantan.

Selection Is Important

ENGELHARD assembled Thermocouples insure maximum efficiency from their pyrometer instruments because each is made up from selected individual parts, chosen because of their ability to meet the requirements of a specific application.

Whether the atmosphere encountered is reducing, oxidizing or corrosive—the maximum temperatures likely to be encountered, probable quick changes in temperatures, how often the thermocouple will be removed or the lead wires disconnected—these are only a few of the main points in successful thermocouple selection.

Take your Thermocouple problems to Engelhard!

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90 CHESTNUT ST., NEWARK, NEW JERSEY

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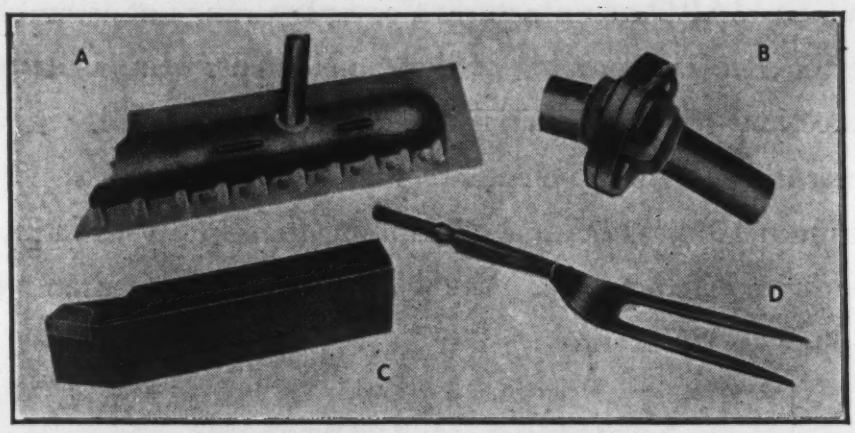
NO. 217 SILVER BRAZING ALLOY

APW No. 217 is tops for low temperature production brazing of steel, stainless steel, alloy steel, copper, brass, bronze, Inconel and monel metal. Only small amounts are needed to make clean, sound, leak-proof joints.

Tested and approved by leading manufacturers . . . here are a few typical applications:



A-Stainless Steel & Copper Refrigerator Sub-Assembly. B-Brazed Steel Universal joint. C-Carbide Tool Tip brazed to Shank. D-Stainless Steel Fork Assembly.

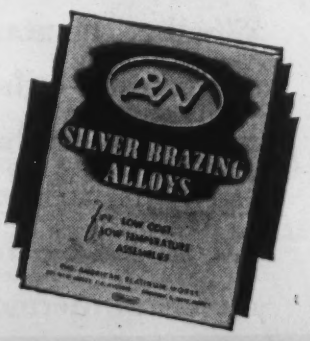
APW NO. 217 ALLOY IS FURNISHED IN WIRE COILS, STRIP, SHEET, WIRE RINGS, WASHERS, DISCS AND SPECIAL INSERTS.

ANY FORM • ANY SIZE ANY QUANTITY.

THERE'S AN APW LOW TEMPERATURE SILVER BRAZING ALLOY FOR EVERY PURPOSE

APW No. 369 PASTE FLUX

Gives maximum protection to metal surfaces being joined and actively promotes flow of molten alloy. Easily soluble in hot water.



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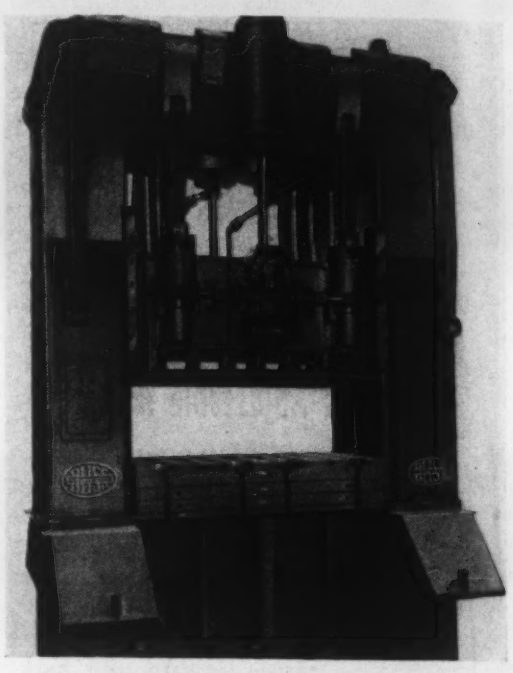
PRECIOUS METALS SINCE 1875

Triple Action Drawing Press Developed for Stampings

The development of a new toggle press line for triple action drawing of large automobile stampings in a wide range of capacities and in any widths desired has been announced by *E. W. Bliss Co.*, Detroit 2. These new presses have 4-point suspension on both the upper slides which are accurately timed and mechanically locked with a crank driven plunger in the bed.

The location of the driving mechanism below the bed permits a reduction in the machine's height above the floor, providing a low center of gravity. Greater stability is



These drawing presses have a low center of gravity providing for greater stability.

accomplished with increased footing front to back.

With triple geared driving mechanism, which consists essentially of motor, drive shaft, and intermediate gearing, the lower plunger is driven by two main crankshafts supported by individual crowns beneath the press bed. The main gears, mounted on the outer ends of the crankshafts, have hubs on each side which are the eccentrics, driving the upper plunger and blankholder mechanisms. Each corner of the blankholder can be power adjusted either independently or can be synchronized with the other three corners.

This system of toggle linkage gives an unusually long dwell to the blankholder; also a sufficient dwell to the upper plunger to perform redraw work with the lower slide.

● A new type of ceramic or vitrified bonded grinding wheel, known as Series 20, has been developed by the *Carborundum Co.*, Niagara Falls, N. Y. In this wheel factors that interfere with cutting action have been reduced and, factors contributing to higher cutting efficiency have been increased. Among its uses are surface grinding (horizontal spindle), tool and cutter grinding, and surface and cylindrical grinding of forms.

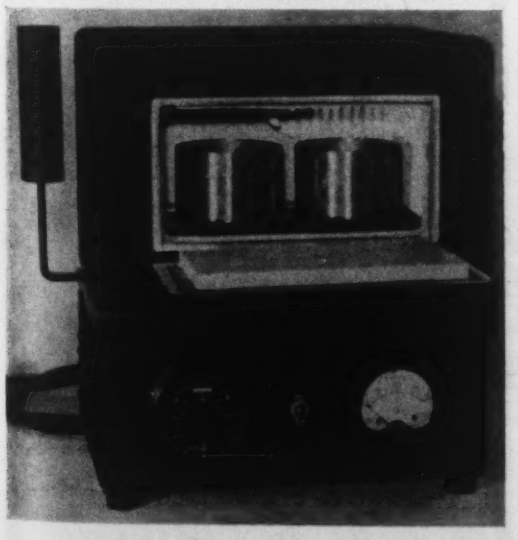
The *Jessop Steel Co.*, Washington, Pa., and the *Alan Wood Steel Co.*, Conshohocken, Pa., have integrated their technical and manufacturing facilities for large tonnage production of stainless clad steel sheets. Jessop is a leading producer of stainless and stainless clad steel, as well as tool and alloy steel and other specialties, while Alan Wood Steel Co. has been producing open hearth steels for 120 years. Their cooperative product will therefore contain low alloy, high strength steel as a core with stainless steel on the outside, appropriate for automobile bumpers, home appliance manufacturers, and others.

Electric Furnace Has Attached Pyrometer

A new small capacity electric furnace with attached pyrometer and modern percentage timer has been announced by the *Jelrus Co.*, 136 W. 52nd St., New York. It contains a corrugated refractory muffle for uniform diffusion of heat. The muffle is wound on the outside with nickel chrome resistance wire to insure maximum life of the winding.

The inside muffle dimensions are 4⅜ in. deep by 4 in. high, with the door opening being 9 in. wide. The shallow wide muffle is a departure from the conventional design and was adopted to allow the insertion or removal of several items without disturbing the others.

The percentage timers will maintain a constant temperature anywhere between 100



Parts in the small capacity electric furnace to be heat treated. Note wide door opening.

and 1800 F, or may be used to regulate the speed of heating to a required temperature.

For the laboratory or experimental shop, this electric furnace is equally adaptable to enameling, heat-treating, chemical drying, small scale production and similar fields. This furnace is only for 110- to 120-v. a.c. operation.

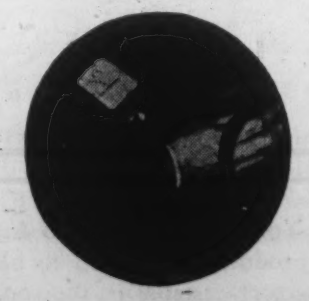
CHECK BLOWERS AND EXHAUST SYSTEMS *Instantly* with the Alnor Velometer

This instantaneous direct reading air velocity meter measures air speed in feet per minute. There are no calculations, no timing, no conversion tables; its use is so simple that anyone can take accurate measurements with the Velometer. Extension jets permit correct readings in many locations that would be difficult or impossible to reach with other means of measurement.

Keep exhaust equipment working efficiently by regular checks for draft, leaks, blower operations, etc., with the Alnor Velometer. You can get accurate information on performance with a few minutes' inspection at regular intervals.

The Velometer is made in several standard ranges from 20 fpm to 6000 fpm and up to 3 inches static or total pressure. Special ranges available as low as 10 fpm and up to 25000 fpm velocity and 20 inches pressure. Write for Velometer bulletins.

Velometer used for positive static pressure readings



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7 Ways to Improve Sulfuric Acid Pickling

TO streamline your pickling room procedures, try the new Oakite Pickle Control No. 3 in your hot sulfuric acid solution. This effective Oakite material improves your pickling these 7 ways:

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2. **Reduces evolved hydrogen; minimizes fumes.**
3. **Lessens acid attack on metals; lowers hydrogen embrittlement.**
4. **Produces cleaner work.**
5. **Rinses more completely; leaves less smut.**
6. **Extends solution life.**
7. **Saves acid and pickling time.**

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Today . . . arrange with your local Oakite Technical Service Representative for an actual in-plant demonstration of Oakite Pickle Control No. 3. Or ask us to send you complete data. No obligation either way.

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Specialized Industrial Cleaning
MATERIALS • METHODS • SERVICE

Machines for Automatically Welding Contact Materials

Automatic contact type point or disk welding machines, originally developed by the Western Electric Co., have now been redesigned and improved by the *Sheffield Corp.*, Dayton 1, Ohio.

Production on the automatic contact type point or disk welding machines varies from 1200 to 2400 contacts per hr.

With either type of machine it is said that accurate and secure placement of electrical contact material on contact springs can be accomplished at a high rate of production. The spring is loaded in a suitable holding fixture and moves through a series of stages. In the case of the disk machine, it involves punching the disk and placing it at the proper location on the spring, welding the two together, and the final operation of shaping the contact to required flatness or contour.

The machine has a capacity of 83 cycles per min., and production within this capacity is limited only by the operator's ability to load the springs in holding fixture. Actual production varies from about 1,200 to 2,400 contacts per hr. Another important feature is the saving of metal through welding when compared to the rivet type of contact. Control of welding current is made possible by use of an electronically operated panel. When the amount of ampere seconds has been determined for a particular size and shape of contact, the current is controlled automatically.

● A concrete which withstands temperatures as high as 3000 F has been developed by the *Babcock & Wilcox Co.*, 85 Liberty St., New York 6. Known as B & W Kaocast, the product is designed to fill a need for a refractory castable in the construction of industrial furnaces operating at temperatures ranging from the top limit of standard refractory castables up to as high as 3000 F. The material is said to have good stability and resistance to spalling under repeated heating and cooling cycles.

"Here is another example of SUPERKOOL superiority for precision grinding"

. . . excerpts from D. A. Stuart Oil Co. Performance Report on SUPERKOOL 31K

PROBLEM: Precision grinding finish of 4 to 6 micro inches required on compressor valve units, using a 500 grit wheel on Norton Hyprolap machines. Previous mixture of 1 part kerosene and 2 parts red engine oil unsatisfactory.

SOLUTION: Use of a 1 to 1 blend of SUPERKOOL 31K and kerosene.

RESULTS: Operator reported less mist from the machine...Production increased to 200 pieces...Finish improved 2 to 4 micro inches...subsequent tests proved completely satisfactory results by using SUPERKOOL 31K straight on micromatics, and the above dilution on the Hyprolap machines... Foreman and lubrication engineer well pleased...orders for SUPERKOOL 31K to be placed as required.

O. M. Gibson

D. A Stuart Oil Co., Representative

STUART *service goes with every barrel*

WRITE FOR DETAILS

D. A. Stuart Oil Co.

2745 SOUTH TROY STREET, CHICAGO 23, ILL.

Infra-Red Used for Degreasing and Rustproofing

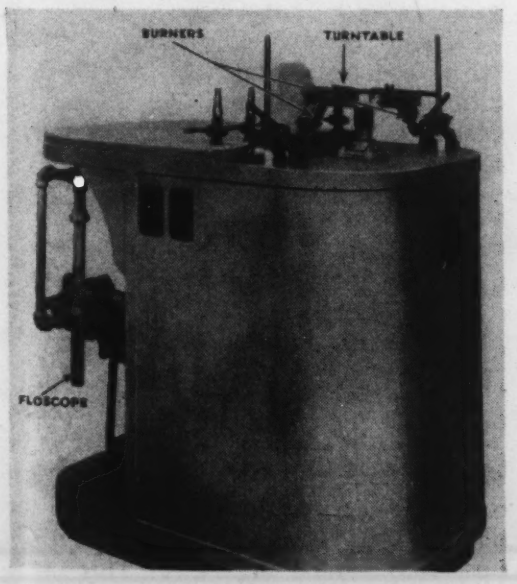
Infra-red equipment for degreasing and rust proofing metal surfaces has been announced by *Burdett Manufacturing Co.*, 3433 W. Madison St., Chicago. This burn-off method of degreasing is accomplished with gas-fired infra-red burners. Besides removing grease, the process simultaneously produces a blue surface on the metal that is rust resistant. This blue surface of the metal is said to be a tight scale that reaches hidden surfaces to do a thorough job.

Sheets treated in this manner have been tested under severe weather conditions for as long as 5 weeks without rusting. Tests have also been run successfully in acid atmospheres. Paint adhesion is said to be equal or superior to adhesion on surfaces treated with liquid rust preventives.

Heat-Treat Table Flexible to Many Sizes and Shapes

Annealing, hardening, silver-brazing, soft soldering and other heat treating operations can be handled on a new heat-treat table designed and manufactured by the *Selas Corp. of America*, 42 S. 15th St., Philadelphia 34. A revolving variable-speed jig-table accommodates work pieces of many sizes and shapes.

Two burners, having a turn down ratio of 40 to 1, are adjustable to any position. Additional burners or different types of burners can be supplied as required.



This heat-treat table handles the work quickly and economically at production speeds.

To maintain fuel at the particular proportions and pressure required by each job, air and gas pass through Floscopes (visual flowmeters) to a Selas combustion controller. An automatic fire check (F.M. approved) guards the mixture line.

HOW THE WROUGHT BRASS INDUSTRY CONSERVES METAL

No industry melting *commensurate tonnage of vital metal can quite match the brass mills for conservation and low melting losses. The savings of metal total millions of pounds; clearly the method they use is worth noting:**

Virtually all the brass mills in North America use the Ajax-Wyatt induction melting furnace, for it has the lowest metal losses in the field — less than 1% — with superior temperature control and unapproached economy of operation on high production schedules such as we have today.

The accepted melting tool in brass rolling mills throughout the world.

AJAX ELECTRIC FURNACE CORP.
1108 Frankford Avenue
PHILADELPHIA 25, PA.

* UPWARDS OF 5 BILLION POUNDS ANNUALLY

THE AJAX WYATT INDUCTION MELTING FURNACE

ASSOCIATE COMPANIES: AJAX METAL COMPANY, *Non-Ferrous Ingot Metals and Alloys for Foundry Use*
AJAX ELECTROTHERMIC CORPORATION, *Ajax-Northrup High Frequency Induction Furnaces*
AJAX ELECTRIC COMPANY, INC., *The Ajax-Hultgren Electric Salt Bath Furnace*
AJAX ENGINEERING CORPORATION, *Ajax-Tama-Wyatt Aluminum Melting Induction Furnaces*

CHUCKING IRREGULAR PARTS?

Production time and money can be saved in making chuck jaws for holding irregular shaped pieces by the Cerromatrix method.

Low-temperature-melting Cerromatrix can be cast against die castings, forged metal parts, rubber, wood and most molded plastics without danger of burning or warping.

Cerromatrix can be poured at 250° F., has a Brinell hardness of 10 and expands slightly after casting. These features make it ideal for constructing split jaw chucks and nesting jigs. Can be reused indefinitely.

Attach the coupon to your letterhead to receive the Cerromatrix Manual which will give you full details.

Makers of Cerrobase, Cerrobend, Cerrolow, Cerrosafe and Cerrotru.

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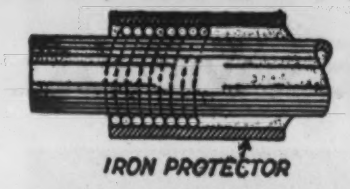
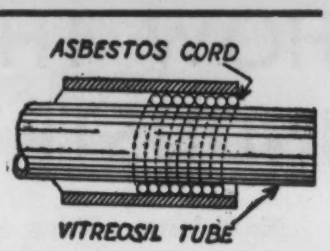
Dept. 8, 40 WALL ST., N. Y. 5, N. Y.
Please send me your Cerromatrix Manual.
Name ..... Title .....
Company .....
City ..... State .....



VITREOSIL TUBES



Protect your Gas Sampling against errors

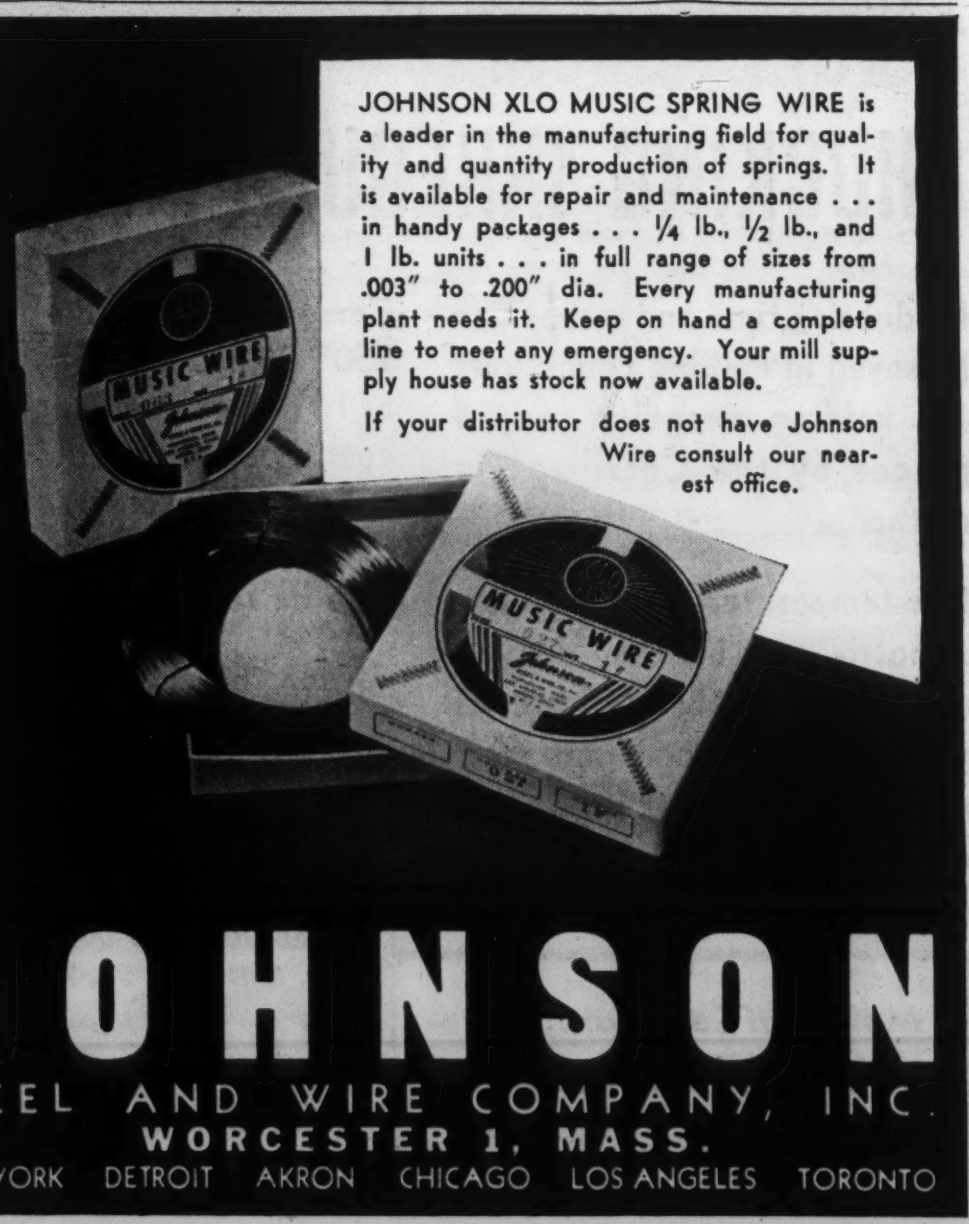
● Unsuitable, unprotected iron tubes may nullify your gas sampling, introduce serious errors. Vitreosil (Vitreous Silica) tubes avoid all danger of contamination. They cannot rust. They are indifferent to thermal shock; chemically inert, non-porous. When properly protected, vitreosil tubes give long life. May be water-cooled.

● The use of Vitreosil for Gas Sampling is fully covered in Vitreosil Bulletin No. 3. We will be glad to send you a copy; also to answer any specific questions you may care to ask us.

VITREOUS SILICA — VITREOSIL — REG'D TRADE MARK

Write for Bulletin 3.

THE THERMAL SYNDICATE, LTD.
12 EAST 46th STREET, NEW YORK 17, N.Y.



JOHNSON XLO MUSIC SPRING WIRE is a leader in the manufacturing field for quality and quantity production of springs. It is available for repair and maintenance . . . in handy packages . . . ¼ lb., ½ lb., and 1 lb. units . . . in full range of sizes from .003" to .200" dia. Every manufacturing plant needs it. Keep on hand a complete line to meet any emergency. Your mill supply house has stock now available.

If your distributor does not have Johnson Wire consult our nearest office.

JOHNSON

STEEL AND WIRE COMPANY, INC.
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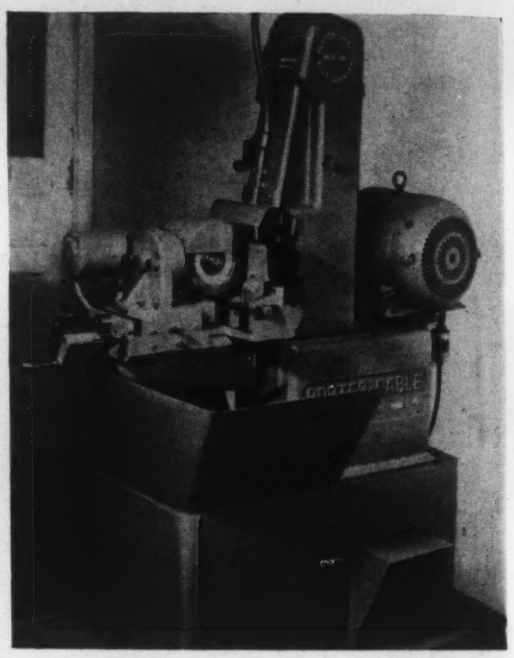
NEW YORK DETROIT AKRON CHICAGO LOS ANGELES TORONTO

Centerless Grinder Uses Wet Abrasive Belt

A centerless wet belt grinder has been added to the line of wet belt machines manufactured by *Porter-Cable Machine Co.* of Syracuse, N. Y.

In this grinder an endless abrasive belt operates over a resilient contact roll. Since the abrasive belt and the contact roll are balanced, the two cut uniformly. The work is done by the abrasive belt; therefore, the contact roll gets a minimum of wear. This roll, which backs up the abrasive belt, therefore remains flat across and square at the corners and its diameter remains constant.

The resiliency of the contact roll eliminates chatter. A soft resilient roll follows



The usual advantages of wet belt machining are achieved with this wet belt centerless grinder.

a shape and cleans up irregular stock. Semi-hard roll is recommended for accurate grinding.

This new centerless grinder is adapted for through work, short pieces, ¾-in. to 2-ft. lengths and longer, with proper supports. Diameters handled range from 3/32 to 2¼ in.

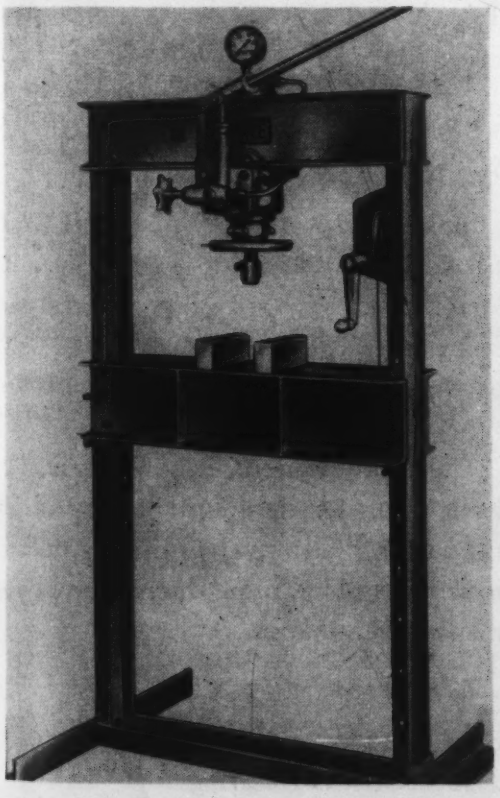
● A new compact, portable Geiger-counter radiation detector has been announced by *North American Philips Co., Inc.*, 100 E 42nd St., N. Y. This instrument is battery powered to adapt it for field survey work. It is invaluable around the laboratory or plant for radioactivity determinations, and is carried by hand or by means of a shoulder strap when employed in such work. The indicating meter shows the rate at which radioactive pulses are received and also is used to determine the potential applied to the Geiger-counter tube.

● A new high-intensity, high-resolution powder camera, developed by *North American Philips Co., Inc.*, 100 E. 42nd St., New York, for X-ray diffraction work, incorporates a new slit system which produces clean film patterns and reduces exposure time. Other features are: (1) precise collimator and beam tube alignment, (2) light-tight cover design, and (3) universal saddle (mount) which adapts the camera for use on existing types of X-ray diffraction apparatus made by Philips or other manufacturers.

New 25-Ton Hydraulic Press Has Fast Moving Ram

A 25-ton hydraulic press, Model 25H, is announced by *Dake Engine Co.*, Grand Haven, Mich. This new press features a fast-moving ram. The extra speed of operation is obtained by using an extra-large pump.

The press is constructed with arc-welded steel channel. A large space between uprights allows the handling of work up to 33½ in. in dia. The screw-type ram provided can be advanced by hand to speed operation.



The fast moving ram in this hydraulic press saves considerable operating time.

Standard equipment includes two combination table and V-blocks, round nose for pressing, pressure gage, and table-hoisting mechanism. The press can also be furnished less the gage and less the table hoisting mechanism.

The press was primarily built for use in maintenance, service and industrial plants requiring an intermediate size press. It complements the larger sizes manufactured by this company, available up to 75-ton capacity.

How do *YOU* measure manpower?

Does manpower in your welding department mean numbers of men—or do you, more logically, measure manpower in terms of production?

Because welding is becoming increasingly important in every phase of production today, it is important that your welding be done faster, better and more economically. If weldors are using cranes or spending time propping up, turning over and flopping their weldments, they are interrupting production and increasing costs on every foot of welding.

Investigate the demonstrated advantages of C-F Hand or Power-operated welding Positioners and see how they can help your weldors produce better, faster and more economical welding. Weldors can swing weldments into any position because every weld is downhand, larger electrodes can be used with resulting savings in time and material. For production welding, C-F Power-operated Positioners are unequalled—equipped with either variable or constant speed table rotation and power tilt, C-F Positioners have been setting new standards in production welding in many varied industries. Write for Bulletin WP-22 and more details. Cullen-Friestedt Co., 1314 S. Kilbourn Ave., Chicago 23, Ill.

C-F

CULLEN-FRIESTEDT, CHICAGO 23, ILL.

positioned welds mean better, more economical welds

It's Here!

The FINELT WAX INJECTOR

. . . acclaimed as the finest machine of its kind. A versatile, precision-made unit, ideally adapted to wax injection into both rubber *and* metal molds . . . can be used as either a hydraulic or air-pressure operated unit.

WATCH FOR THE FINELT MOLD KIT *coming soon!*

Check these features against any other wax injector on the market:

- **Hydraulic or air-pressure operation**
- **Positive temperature control to within two degrees**
- **Positive pressure control to a fraction of a pound**
- **Complete control over the quantity of wax injected**
- **Complete visibility of temperature and pressure at all times**
- **Full two-quart capacity**
- **Designed for rapid wax pattern production**
- **Designed for simple fool-proof operation**
- **Available for operation on any type of electric current**

Write for complete catalog

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64 W. 48th ST. • NEW YORK 19 • DEPT. M

precision casting sales and engineering

TEMPIL°

measures working temperatures

. . . QUICKLY

. . . SIMPLY

. . . ACCURATELY

• MELTS SHARPLY — Tempil° products have a sharp and rapid melting action at stated temperatures . . . are available in *liquid, crayon,* or *pellet* form, as a convenient means of signalling temperatures in a multitude of industrial operations.

• READILY IDENTIFIED — Each Tempil° product is clearly marked with the temperature at which it melts. In addition, Tempil° products are made in a *distinguishing* color for each melting point.

• ACCURACY — Tempil° products have a mean accuracy of within 1% of stated temperature.

• USES — Tempil° products are widely used to: prevent cracks and failures in metal processing; make stronger and safer welds; repair costly castings, forgings and machine equipment; in hard-surfacing, straightening hardened parts, drawing, tempering and local heat-treating.

TEMPILSTIK° In 13° steps . . . 125° F. to 400° F. In 50° steps . . . 400° F. to 1600° F. For welding, forging, heat-treating and fabrication of metals; molding of glass, rubber and plastics, etc.

TEMPIL° PELLETS In 25° steps . . . 125° F. to 350° F. In 50° steps . . . 400° F. to 1700° F. To determine temperatures in heat-treating of large units or extensive areas; checking furnace or engine temperatures; setting induction-heater timers, etc.

TEMPILAQ° In 25° steps . . . 125° F. to 350° F. In 50° steps . . . 400° F. to 1700° F. For heat-treating or processing, particularly on interiors not accessible for Tempilstiks° or Pellets; ideal for glazed or polished surfaces, glass, plastics, etc.

Write Gordon today for Tempil° Preheating Chart, Tempil° scale for weld bend testing and complete information on Tempil° products.

GORDON SERVICE

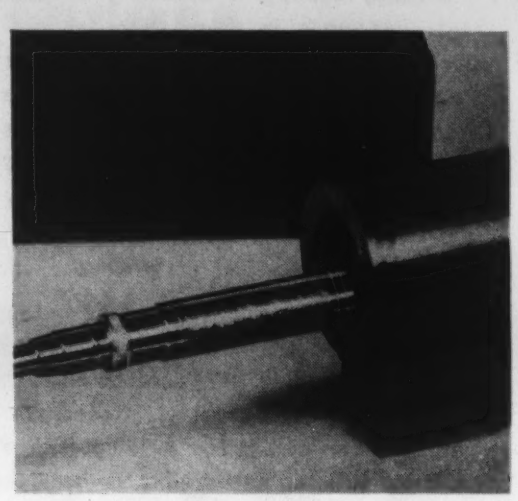
CLAUD S. GORDON CO.

Specialists for 33 Years in the Heat-Treating and Temperature Control Field

Dept. 13 • 3000 South Wallace St., Chicago 16, Ill.
Dept. 13 • 7016 Euclid Avenue • Cleveland 3, Ohio

Tracer Measures Surface Roughness in Deep Bores

A new tracer for taking micro-inch surface roughness measurements in deep bores such as hydraulic cylinders, camshafts and tubing with their profilometer, has been announced by *Physicists Research Co.*, 321 S. Main St., Ann Arbor, Mich. This tracer, known as Type LA, will measure to any desired depth in holes as small as ¾-in.



For use with the Profilometer, this tracer can be used to depths of 36 in. or more.

I.D. The diamond tracing point is self-adjusting to the work surface.

The tracer is mechanically operated by means of a Mototrace and Type BA Linkarm. By using Linkarms of the proper length for each application, measurements can be taken with the one tracer at various depths to 36 in. or greater.

Accessories Developed for Wear Testing Equipment

Two new accessories developed for use with the Taber Abraser in wear-testing materials have been announced by the *Taber Instrument Corp.*, North Tonawanda, N. Y.

The first, an interval timer, is an electrical device which enables research laboratory personnel to control operating time of abrasion tests within prescribed limits, thereby eliminating losses of tests resulting from accidentally running tests past the prescribed end point.

Second is a refacing stone, a development designed for refacing Calibrase-type abrading wheels that provides greatly improved control of wheel surfaces and assures more dependable standardization of wheels than previously possible. Replacing the abrasive-coated paper disks formerly supplied for this purpose, it also gives greater economy in use.

CORROSION RESISTANCE
That's more than skin deep

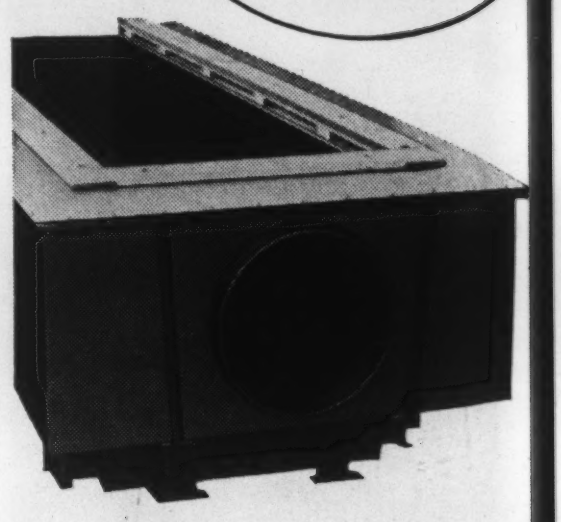
HAVEG

IS

NOT A LINING
NOT A COATING

but a Structural, Non-Corrosive Material

ALL THE WAY THROUGH



Scratch the surface—or gouge out a chunk—and you'll still find HAVEG process equipment fully resistant to the attacks of corrosion. Haveg is resistant to practically all acids, bases and salts, as well as chlorine, many solvents and other chemicals.

Haveg equipment, either standard or built to order, is adaptable for tanks, blowers, agitators, valves, piping, pumps, towers, coolers, fume ducts, hoods and many other shapes.

Send for our Bulletin F-4 with complete engineering and application data.

HA-3-47

HAVEG CORPORATION
NEWARK 25, DELAWARE

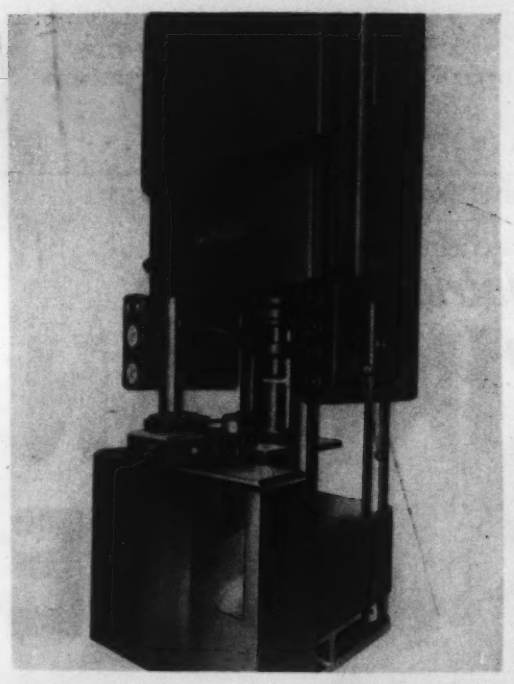
CLEVELAND CHICAGO DETROIT LOS ANGELES

● An adjustable snap gage announced by *Dietrich W. Botstiber*, 300 W. Upsal St., Philadelphia, is intended for hand gaging, for inspection departments and production machines, where relatively close tolerances are required between operations or on finished pieces. Adjustment of the gage can be made to 0.00004 in. This is done by utilizing the elastic elongation of the gage bolts for fine adjustment, which makes the accuracy independent of the pitch of the bolt threads. The gage is furnished in 15 sizes, ranging from zero to 4.75 in.

New 75-Ton Press Has Unique Ram Action Control

A 75-ton press having varied ram action controls, said to be unique in a press of this size, has been introduced by the *Denison Engineering Co.*, 1160 Dublin Rd., Columbus 16, Ohio.

Among its operating characteristics are automatic or manual ram cycling, fast traverse—slow pressing speed, pressure and distance reversal, low ram tonnage if desired with high return and accessory pressures. The press has a 30-in. daylight opening and 18-in. stroke and pressurized filter system.



With a choice of three valve combinations, this press will meet practically all pressing cycles within a 75-ton range.

Adjustments give this press a pressure variance of from 7½ to 75 tons, making it adaptable to a wide variety of different applications.

● A self centering, double cam actuated vise which centers the work to the drill or cutter regardless of the dimensional variation of the piece, has been introduced by the *Williams Products Co.*, Middletown, Conn. The self-centering feature of this vise is of particular advantage in the case of castings, forgings and similar types of unmachined blanks.

POTP

The "Proof of the Pudding" that Amersil's new engineering service pays off in practice, in large or small plants, having problems involving extreme temperatures and highly corrosive operating conditions is illustrated by the case histories shown.

ANNEALED SILICA TRAYS LAST a minimum of 10 TIMES LONGER *Name on request.

Ask an Amersil engineer to explain the new integrated engineering service which includes development, research, design, controlled manufacture of major silica ware units, selection and purchase of auxiliaries—all under one contract one responsibility.

60 TON PLANT 2½ TONS OF 22° B'e ACID AN HOUR ON A 24 HOUR BASIS DESIGNED BY AMERSIL

AMERSIL COMPANY Inc.
CHESTNUT AVENUE ENGELHARD HILLSIDE 5, N. J.

SMALL SIZE MELTER *Is Profitable*

● This reverberatory type furnace delivers 500 lbs. of High Quality molten Aluminum per hour from scrap or pig aluminum. Chips and turnings can also be puddled into fore hearths with exceptionally high recovery rates. Fast—economical, it requires very little floor space.

Offers lower maintenance cost as conventional iron melting pots are eliminated, with no possibility of metal contamination.

Dempsey designs and builds furnaces to meet your heat treating problems—just as this small melter meets the demands for a small, low cost unit to reclaim aluminum scrap.

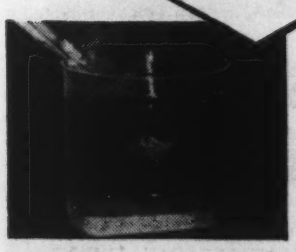
There is a Dempsey representative near you to discuss your problems. Write, phone or wire us—there is no obligation.

Write to Dept. 2

FURNACES: Oil-Gas-Electric-"TAILORED" by DEMPSEY
Meet every Heat Treating Need

DEMPSEY FURNACE DEMPSEY INDUSTRIAL FURNACE CORP.

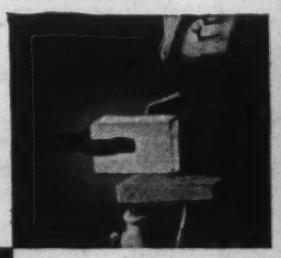
SEND FOR this Brickseal coated BRICK

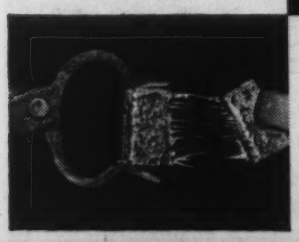


Brickseal penetrates the pores and joints of firebrick and forms a highly glazed ceramic coating many times harder than the brick.

Tough and semi-plastic under heat, it prevents cracking and spalling regardless of temperature change—heat the sample and douse in cold water any number of times.

Brickseal resists abrasion. Force the sample brick, either hot or cold, against an emery wheel and see the difference on the coated and uncoated sides.





Brickseal is a superior mortar for fire walls. Try to pull the sample bricks apart after they are heated to 2200°.

Write today for a free sample. No obligation, of course.

Brickseal

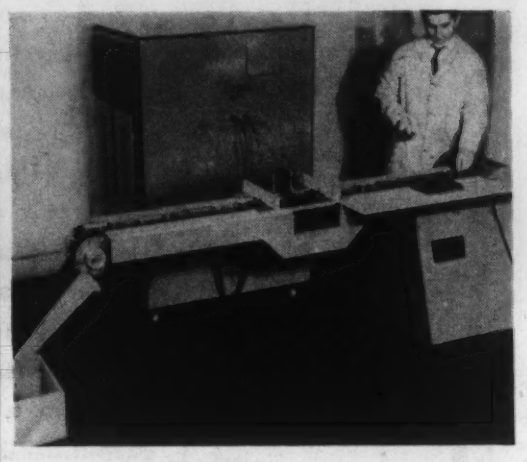
REFRACTORY COATING

5800 So. Hoover Street, Los Angeles, Calif.
1029 Clinton Street, Hoboken, New Jersey

Conveyor Belt Table Increased Induction Heater Output

A new conveyor or a belt table, for use in conjunction with induction heaters, for efficient handling of work parts for brazing, soldering, annealing and hardening, has been developed by *Lepel High Frequency Laboratories, Inc.*, 39 W. 60th St., New York 23,

In the accompanying illustration, the application is the annealing of the top edge of hardened steel wedges, 4 in. long and ¼-in. thick, for the purpose of reworking.



The conveyor belt table set-up being used for annealing top edge of hardened steel wedges at rate of 1800 pieces per hr.

Eighteen hundred pieces per hr. can be annealed with the Lepel 15-kw. unit shown in the background.

This conveyor belt is powered by a ¼-hp. motor, and the belt speed may be regulated over a wide range to accommodate a variety of applications. The conveyor belt proper permits the fastening of interchangeable supports to hold various-shaped work parts in place. The load coil is movable and can, for example, be placed at the extreme left of the conveyor belt for hardening applications, at which point the part falls directly into a quenching tank.

● A new-type double spindle wet grinder designed for grinding double and drop forged engineers' wrenches and many other parts that require grinding of parallel surfaces, is being manufactured by *Charles H. Besly & Co.*, 118-124 N. Clinton St., Chicago 6. The new grinder features a combination magnetic vibrator and automatic chain feed. Using oil as a coolant, the new grinder is capable of turning out 2400 wrenches per hr., measuring 8 in. overall and ground on all four surfaces.

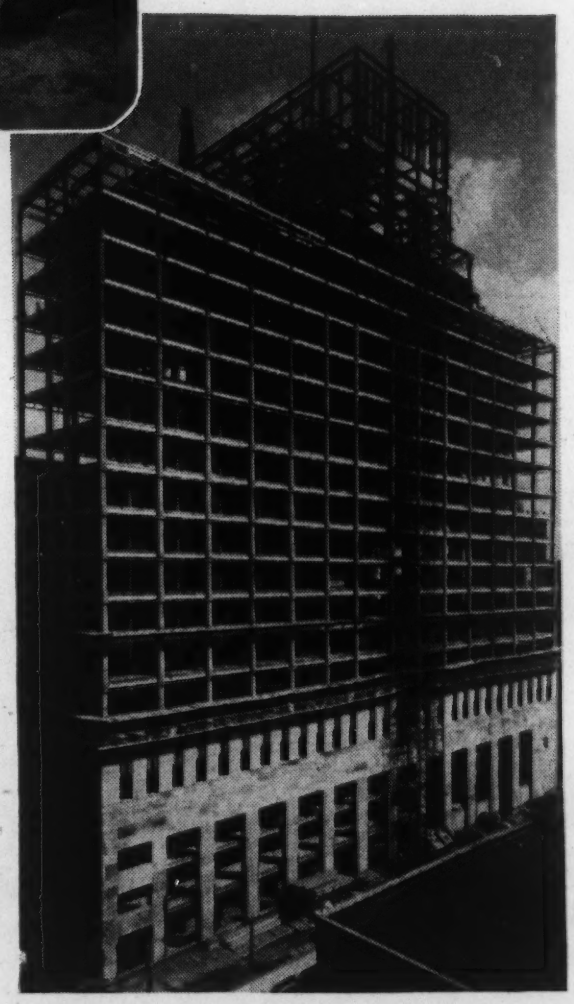
Master Hands on Intricate Jobs use

SHAWINIGAN CARBIDE

SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING,
NEW YORK 1, N.Y.

Cameron Iron • Peterson Bros.

Both use SMITHway *Certified* Electrodes



Cameron Iron Works, Houston, manufactures drilling, completion control equipment, and other specialties for oil-field use, including the Cameron Blowout Preventer, a part of which is pictured. SMITHway SW-15 Electrode is shown in use. Cameron, which also uses many SMITHway high tensile electrodes, knows that the *proof* of SMITHway Electrodes is in production—and in service.

Peterson Bros. Construction Co., Houston, steel erectors, used SMITHway Electrodes throughout in welding the new City National Bank Building, Houston. The first four floors were welded with SW-15, all the other floors with SW-10. Peterson Bros., too, know the value of A. O. Smith welding research . . . research that makes welding the modern tool for *all* kinds of jobs, both large and small.

SMITHway *Certified* Welding Electrodes—Made *by* Welders . . . *for* Welders

ASK FOR THE FACTS ON SMITHway A.C. WELDERS!

Models for every kind of welding job—cover every welding range. Lightweight, compact, highly efficient. Write for specifications and prices.

A. O. SMITH Corporation

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SEATTLE 1 • SAN FRANCISCO 4 • LOS ANGELES 14
INTERNATIONAL DIVISION: MILWAUKEE 1

The Last WORD

by T. C. DU MOND

Materials as Sales Points

The favorable qualities of materials are now recognized rather widely as sales points for the products in which they are used. This may have a beneficial effect, generally, since there is still considerable misapplication of materials. Once the public is educated as to the proper application of materials it can be a powerful force in forcing the reluctant and backward manufacturers into line.

A Burning Problem

Poor magnesium! Despite all of the educational material prepared to prove that as a solid magnesium does not burn you still see and hear many stories which malign this material. For instance, a few weeks ago on a Long Island beach a man picked up a shiny object which looked like a lipstick case. Scarcely had he placed his find in a coat pocket than he found his entire coat ablaze. Quote his doctor: "The object was probably magnesium!" Maybe the eyecatcher was a memento left on the beach by one of the German spies who frequented that area during the war.

Where Steel Stands

When you consider how many other metals and nonmetallic materials are now competing for the applications once considered the sacred property of steel, there may be some inclination to feel that old King Steel is slipping. Save your sympathy! According to a recent release, if the peak production of any year was taken for each of six nonferrous metals, this total tonnage would only be about 20 day's output of steel, at the January 1947 ingot rate. The other metals?—copper, aluminum, zinc, lead, magnesium and tin.

Strange Measurements

Often we hear of strange measuring units. We know of stones for weight and hands for height (a variation is fingers in measuring rye, scotch or bourbon). But now, through Inco's *Process Industries Quarterly,* we learn of the hat as a liquid measure. An early day metallurgist in trying to learn the manufacturing secrets of a rival tin plate manufacturer found that the wrought sheets were pickled in rye water—first in old rye, next in new rye and finally in very old rye. The final bath was conditioned by adding a "hatful" of new rye flour every two weeks.

Production Tips

Speaking of Germans, we learn from a recent government report that in the German war effort they sometimes carried out production-speeding efforts to the Nth degree. As an example, they carried out the carbide tipping of tools to the point of tipping twist drills. Here we make the whole cutting portion of the drill of carbides, when that material seems advisable.

Deep, Dark Secrets

To the uninitiated, it would seem logical to assume the manufacturers would be glad to take advantage of every opportunity to present their products before the public. It's often quite the contrary. Just ask Associate Editor H. R. (Hank) Clauser. In compiling the table on hard-facing materials which starts on page 116, Hank felt somewhat akin to a bill collector or an income tax man. It sometimes took two, three or even four letters to get the desired information. The trouble is that Hank was too fussy, he wanted more and more accurate information than is generally given on these materials. He got it!

From "Black" to "Gray"

We are trying to figure out why the reputed shady dealings in steel, as disclosed in government-sponsored hearings, are referred to as "gray markets." The answer couldn't be so obvious as to be derived from the color of steel—or could it? We hope it indicates that the picture is just a little off from the shiny, bright honest types of trading which is necessary to ward-off the constant threat of government regulation.

Keep an Eye on M & M

The wheels in our editorial minds are spinning at top speed trying to make MATERIALS & METHODS more valuable to its readers. We would like to tell you of some of the projects under consideration and improvements pending, but maybe we'll restrain ourselves for a while longer. We would advise you to keep a close watch, however, for even though we continue to receive glowing tributes to our present effort we are constantly searching for ways in which we can improve.

What's Your Achievement?

Have you entered your most prideful accomplishment of the past year in the MATERIALS & METHODS Achievement Award Competition? If not, you had better do so, for the deadline is rapidly approaching. You will be in very good company, for many of the most progressive companies in the United States have signified their intention of trying for the award.

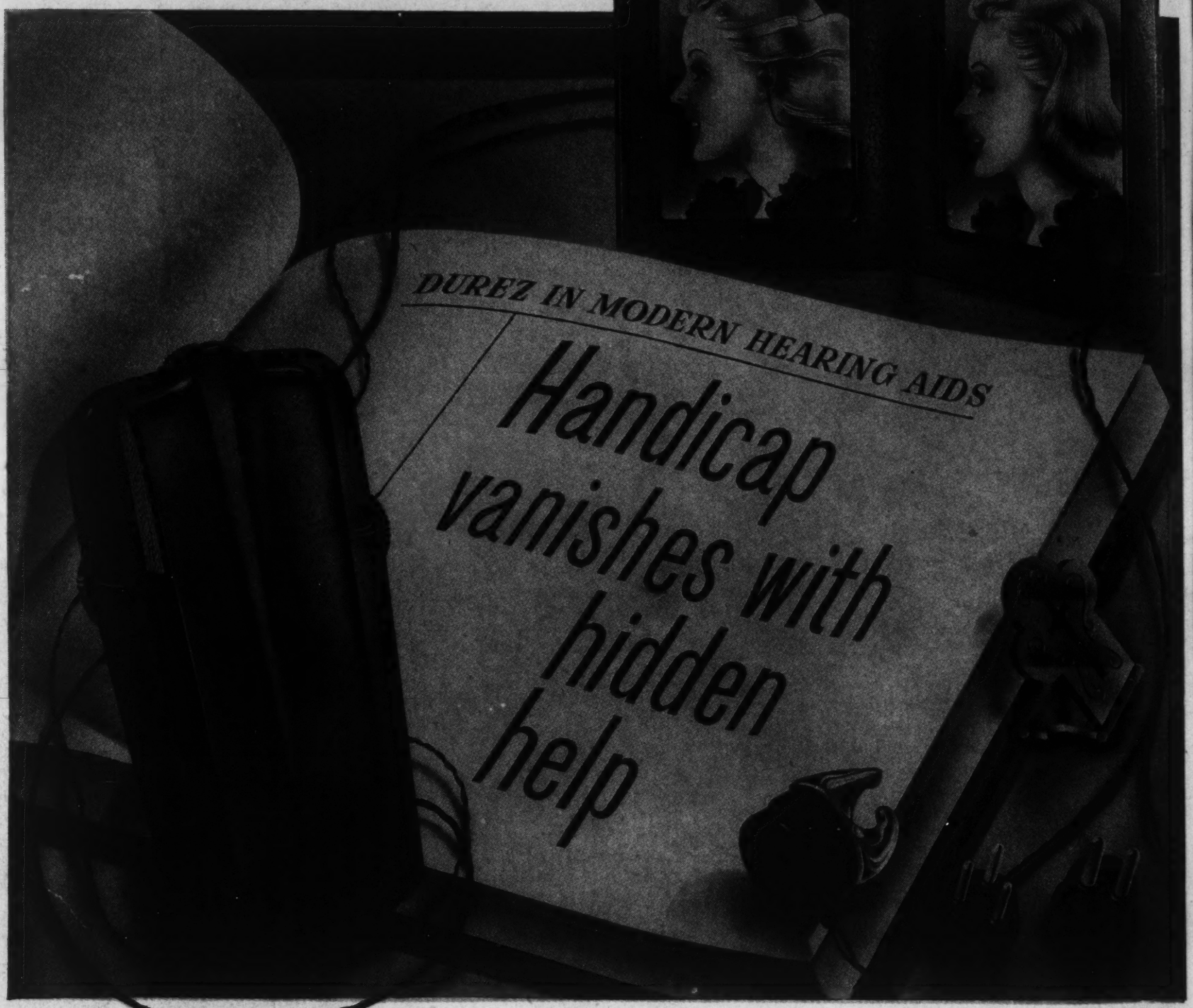
FINIS

Materials & Methods

Economics of Aluminum and Magnesium Alloys

Machining Industrial Timing Mechanisms

★ *New Pages from the* **DUREZ** *Diary*



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